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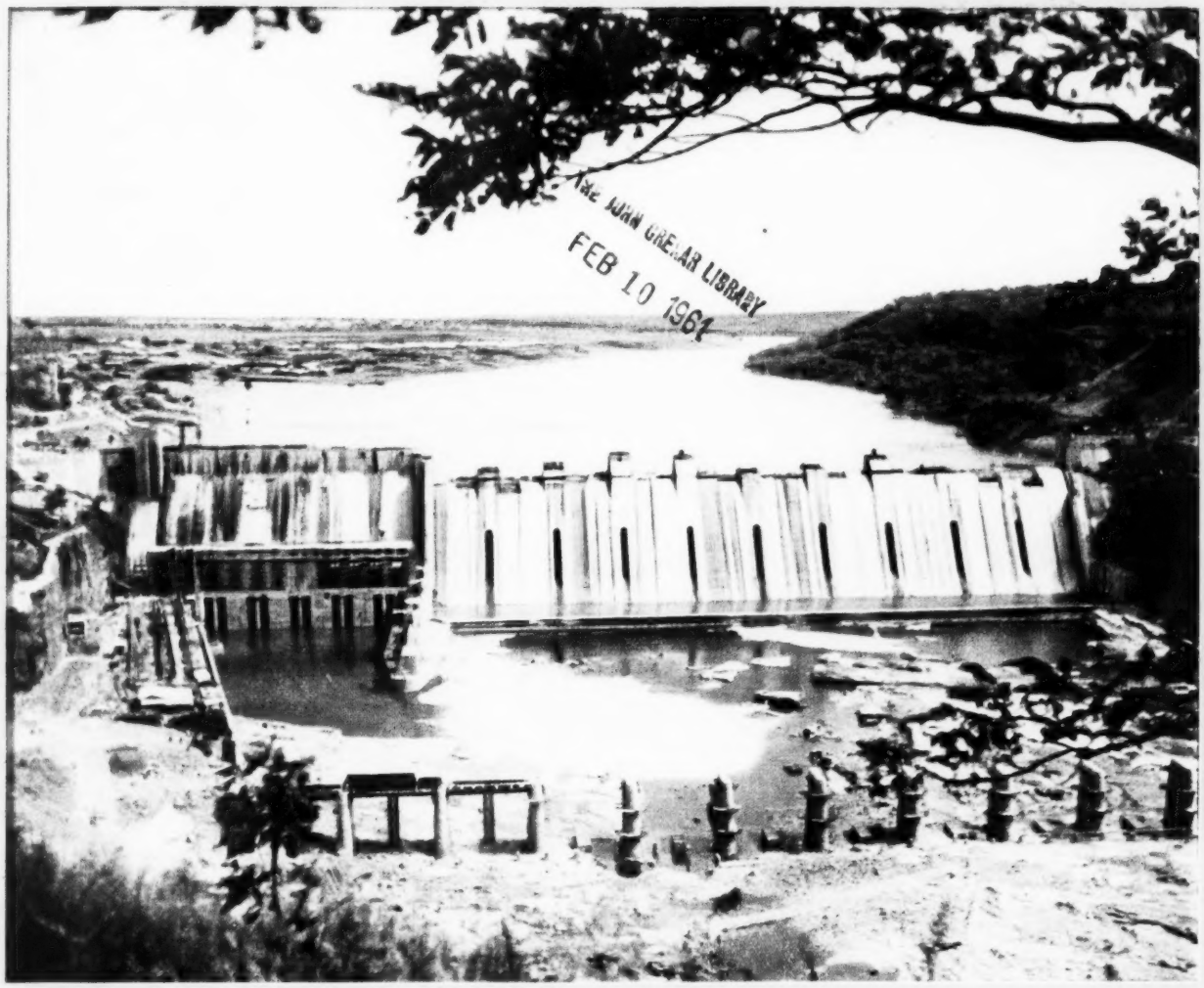
163

INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

CHAMBAL PROJECT NUMBER

VOL. X NO. 10 OCTOBER, 1960 RUPEES TEN



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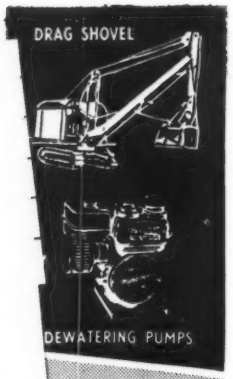
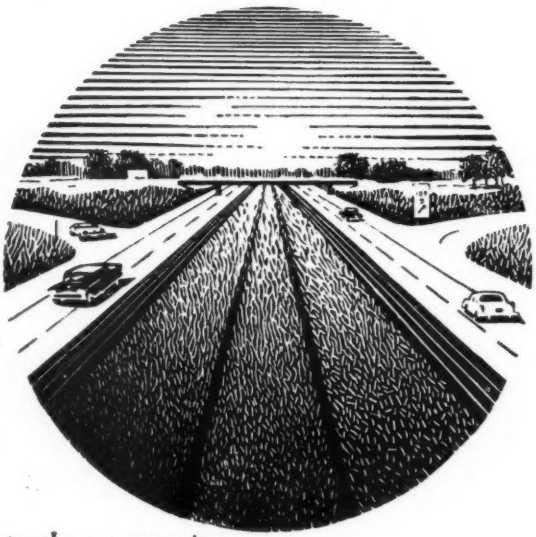
GANDHISAGAR DAM AND POWER HOUSE



roads just like these



View of an American Roadway

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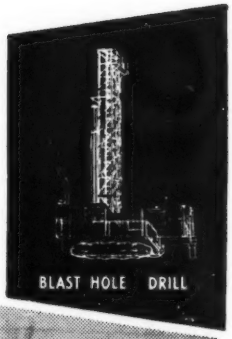

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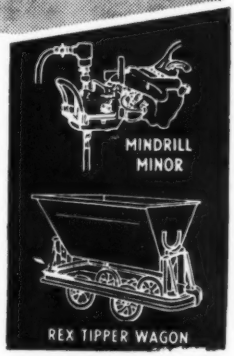

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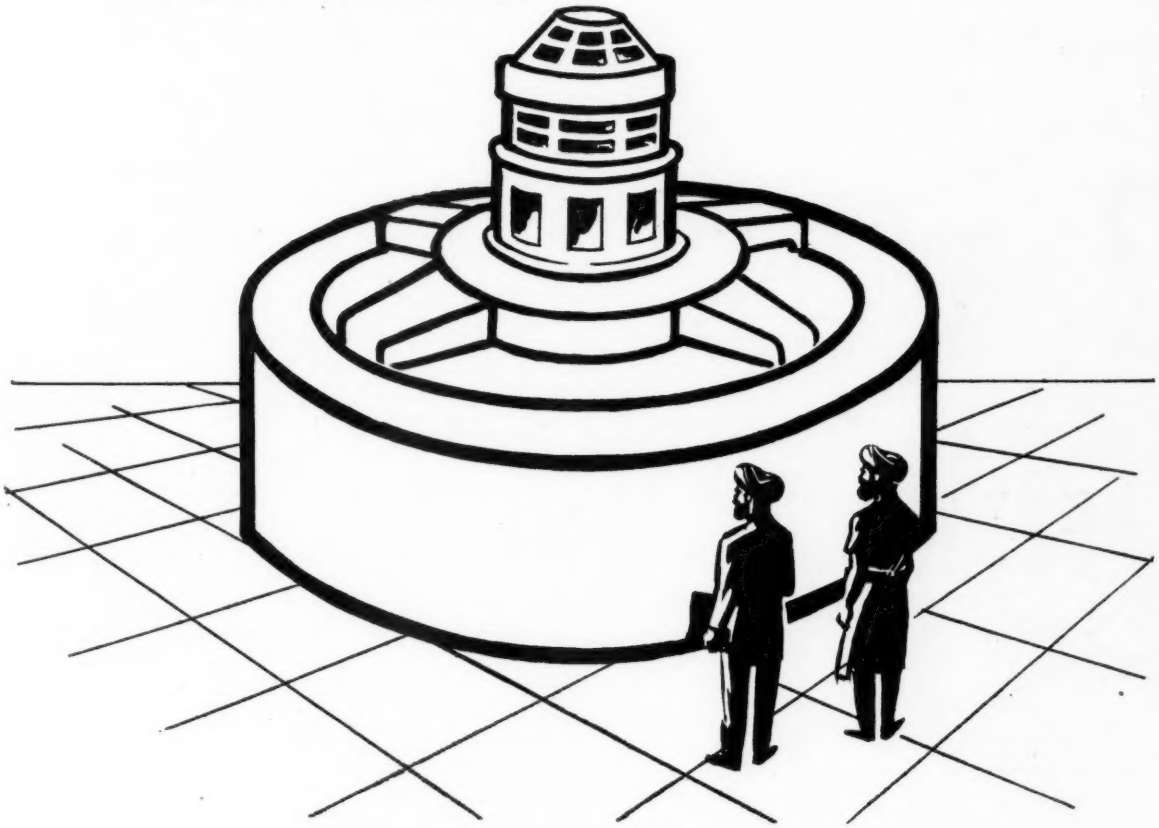

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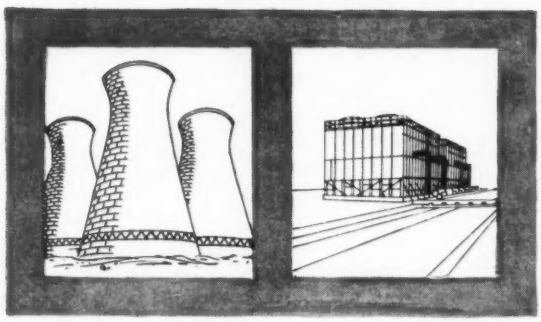

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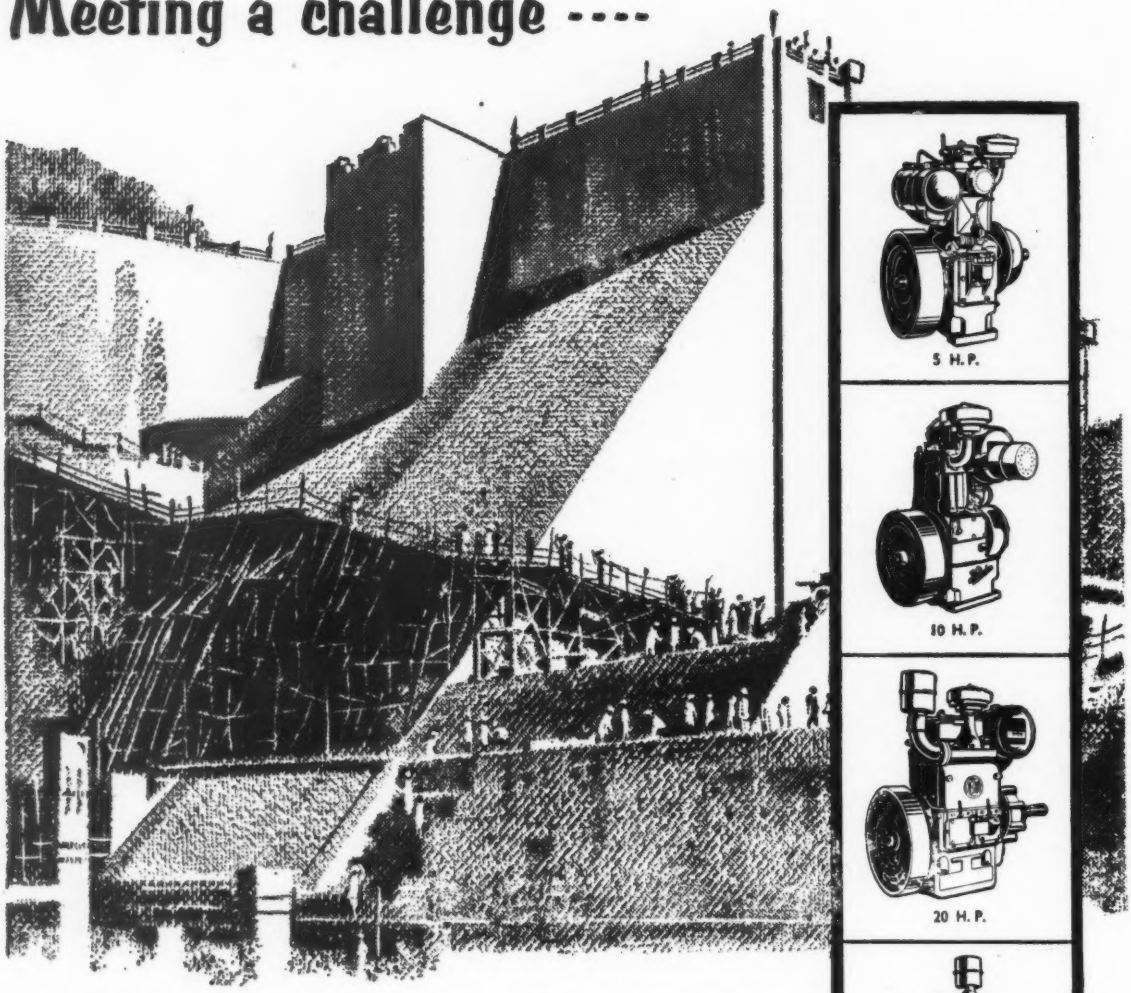

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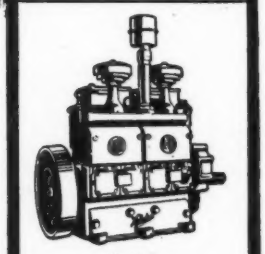
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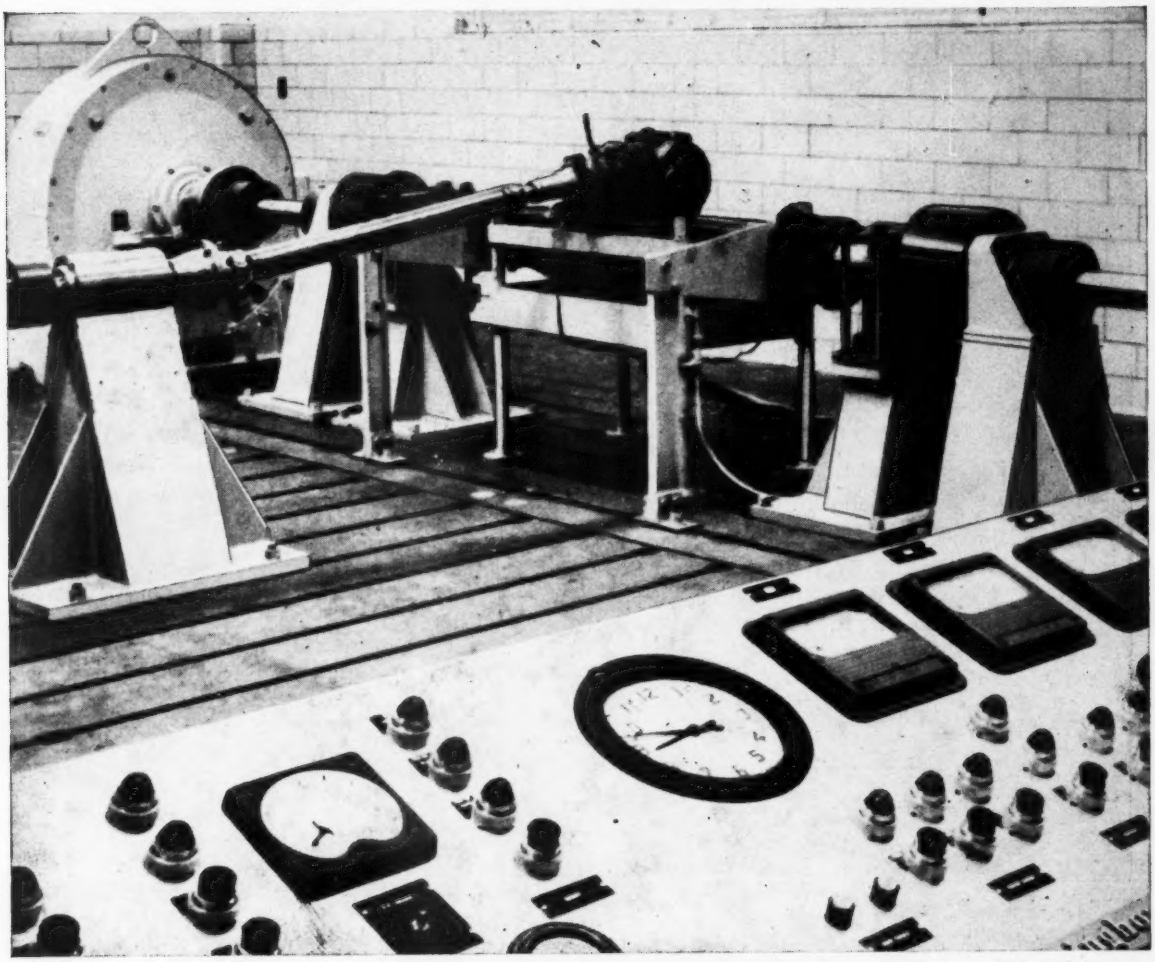

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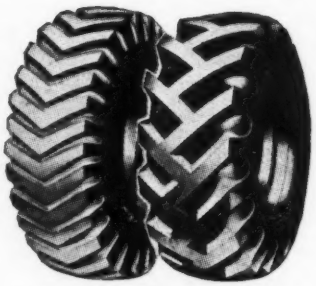

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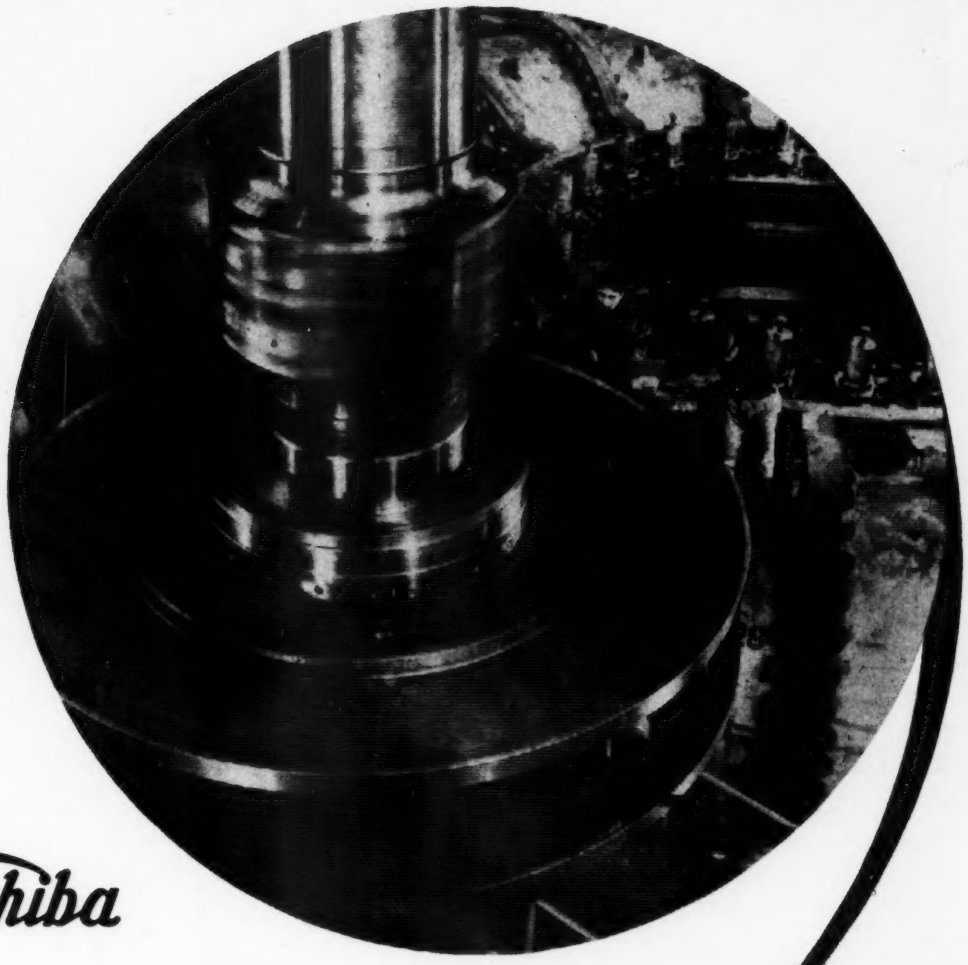

Toshiba

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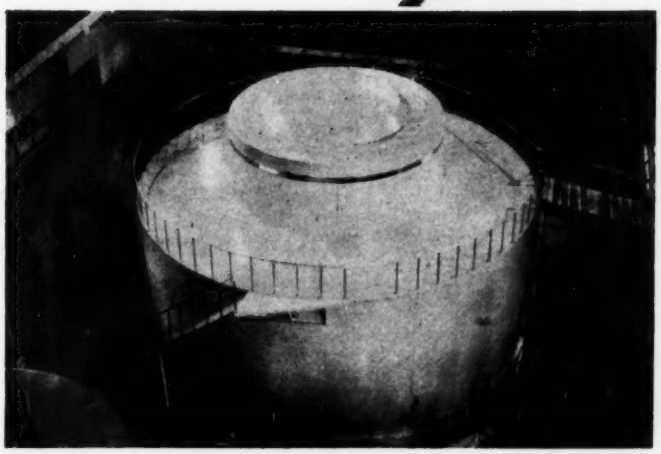

TOKYO SHIBAURA ELECTRIC CO., LTD.

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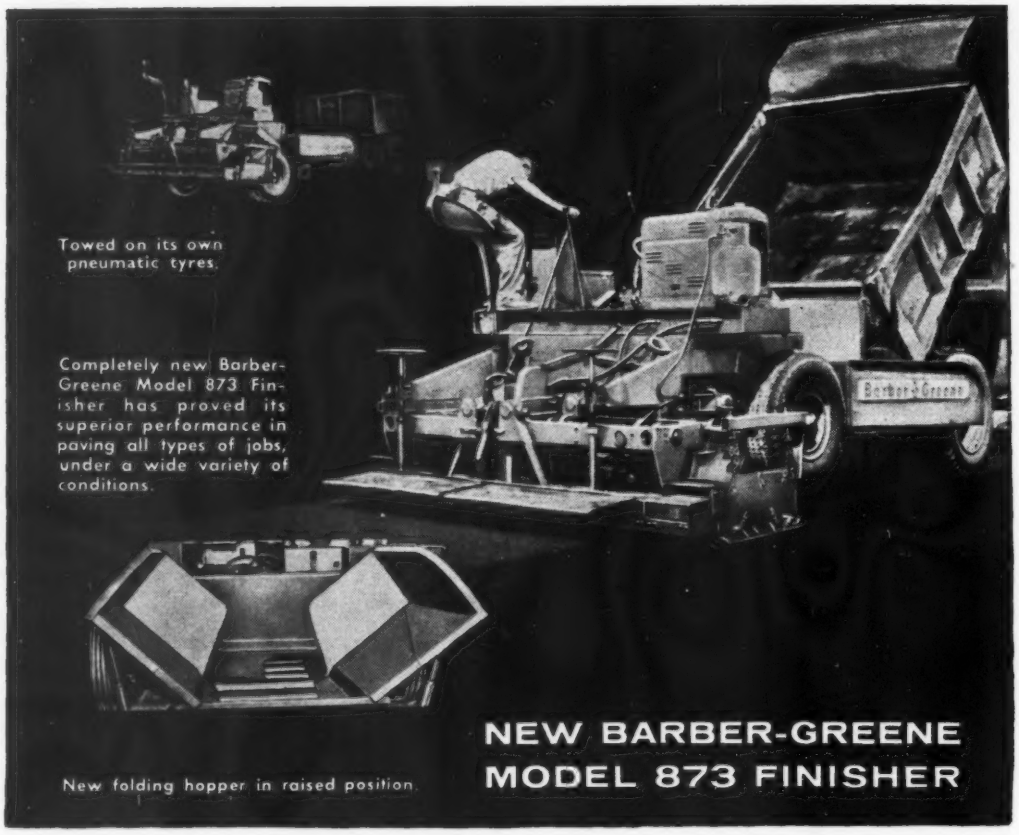
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Completely new Barber-Greene Model 873 Finisher has proved its superior performance in paving all types of jobs, under a wide variety of conditions.
New folding hopper in raised position.
NEW BARBER-GREENE
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paves on crawlers . . . travels on rubber

With crawler traction and flotation for the variety of bases encountered in paving all types of jobs—and trailed at truck speed on its own hydraulically retractable pneumatic tyres, this new finisher includes advancements never before available.

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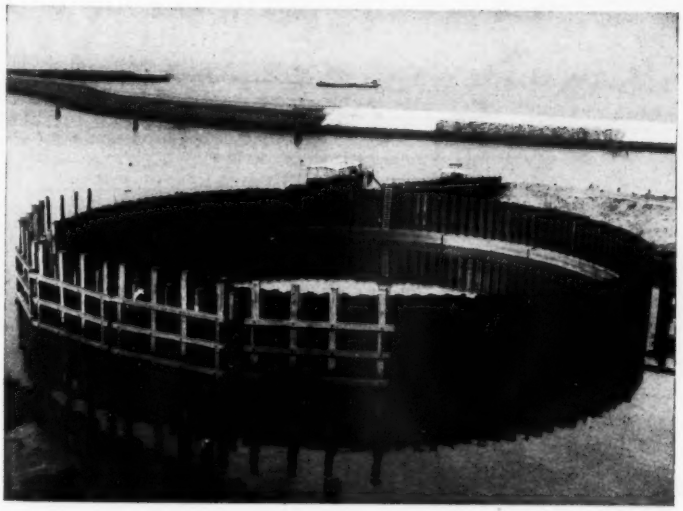

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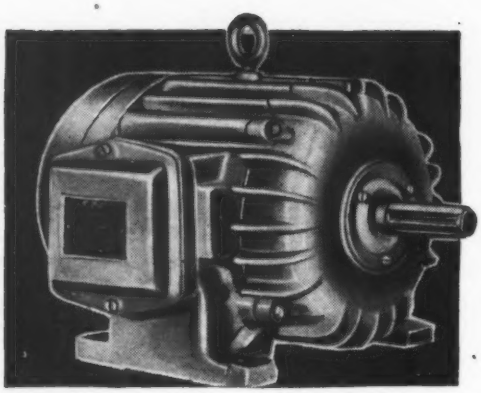

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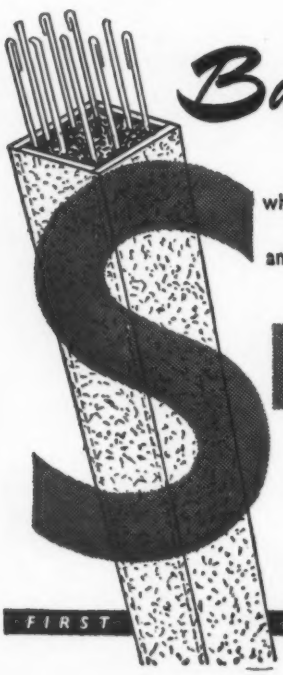

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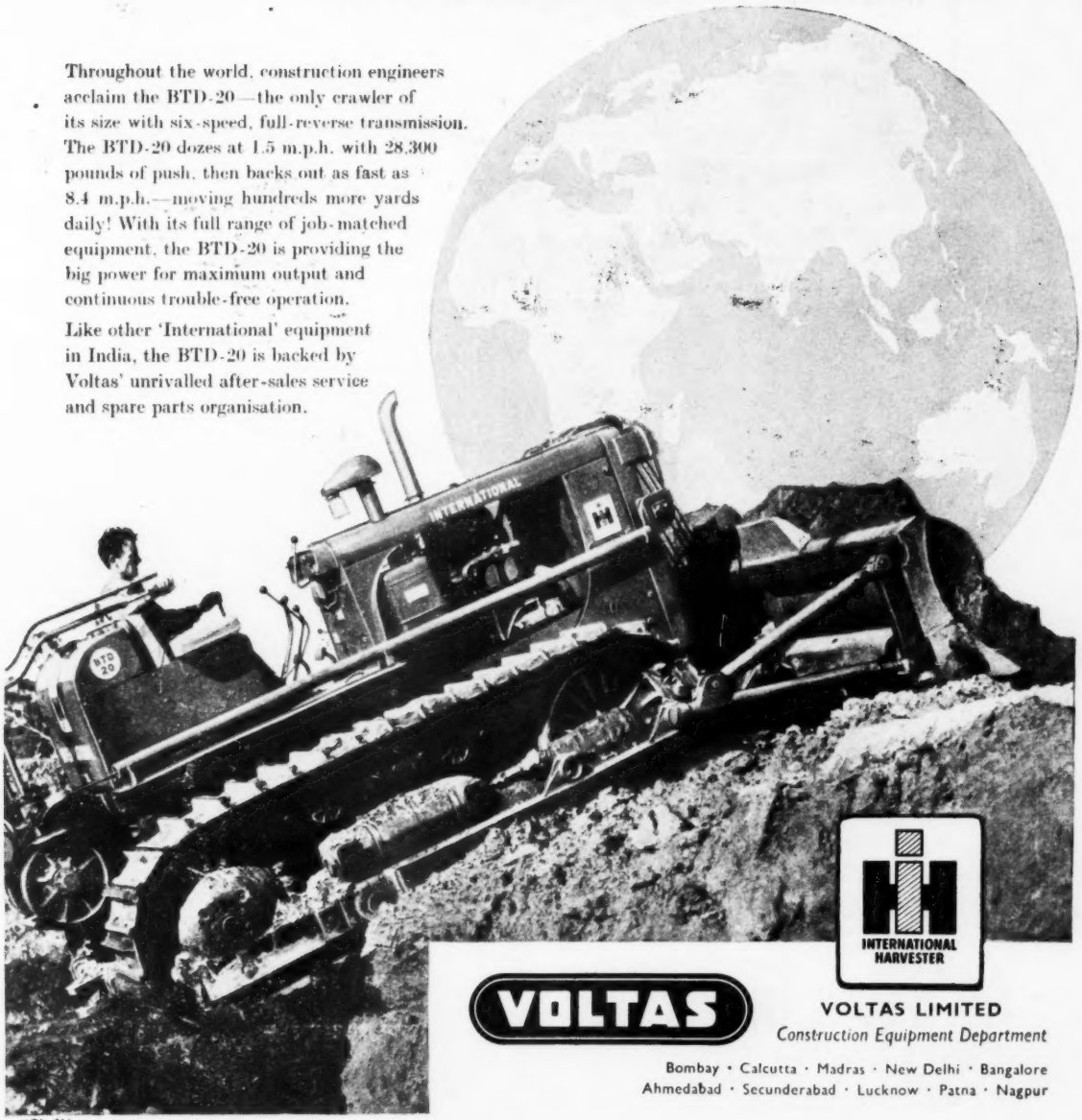

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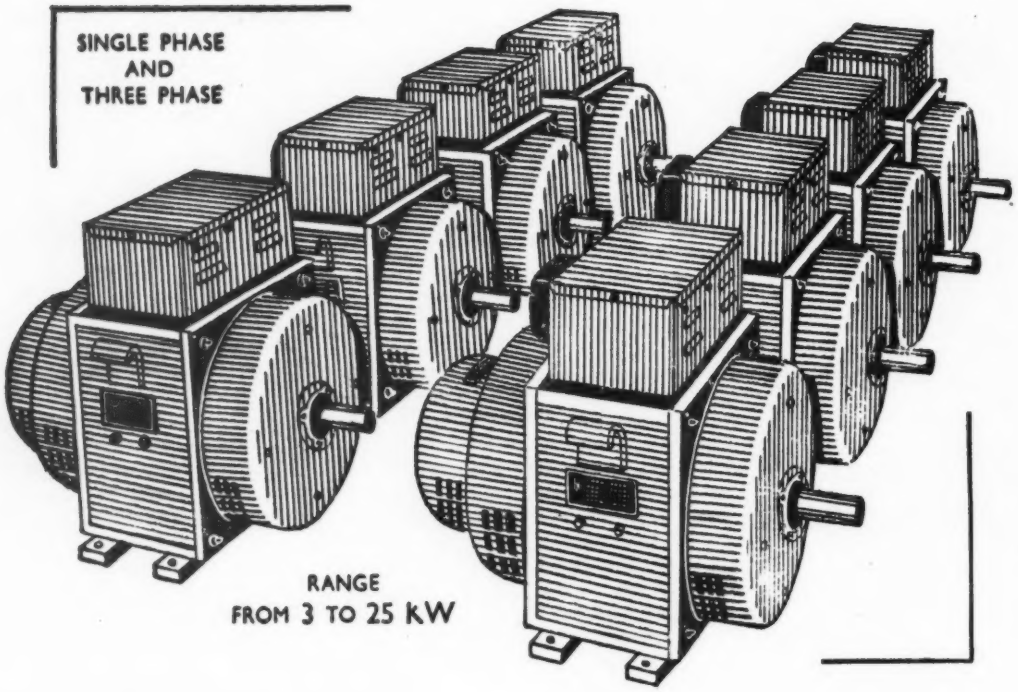

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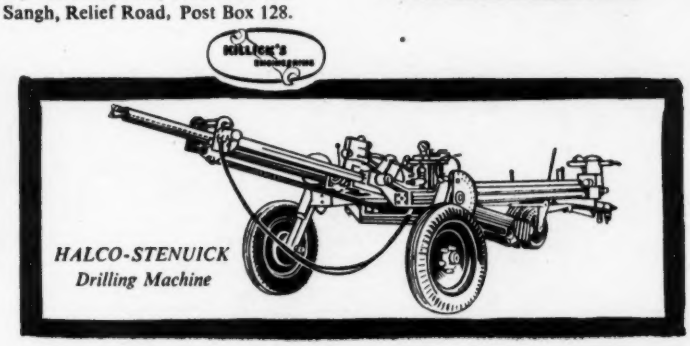

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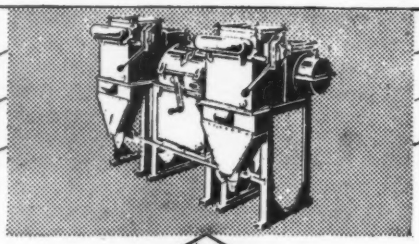

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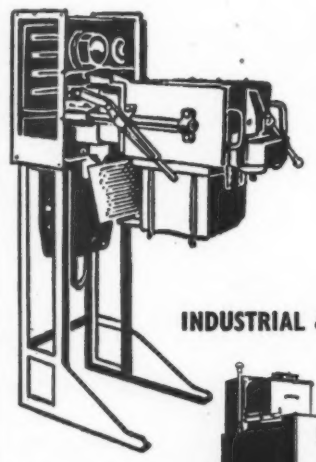
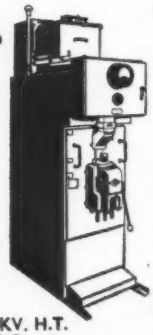
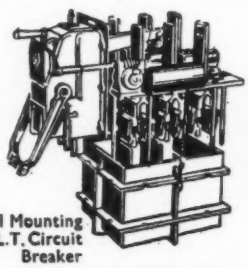


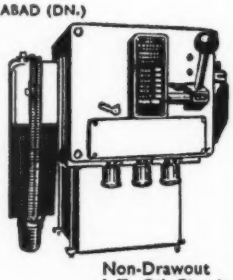
Horizontal L.T. Drawout Circuit Breaker



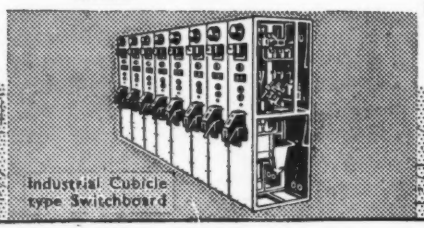
11 KV. H.T. Oil Circuit Breaker



Panel Mounting L.T. Circuit Breaker



Non-Drawout L.T. Oil Circuit Breaker



Industrial Cubicle type Switchboard

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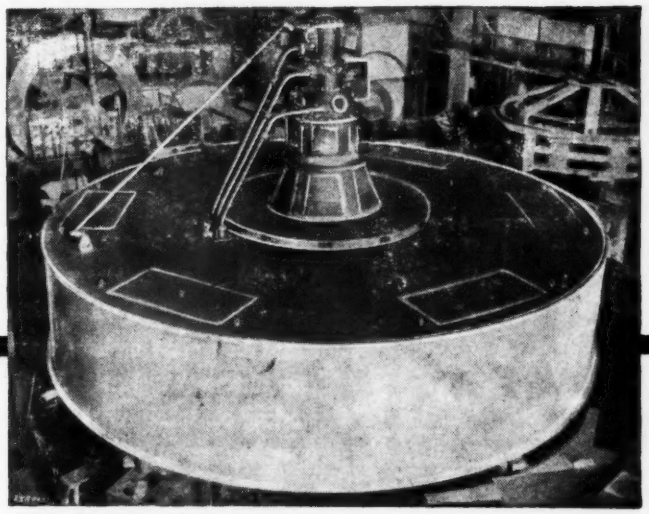

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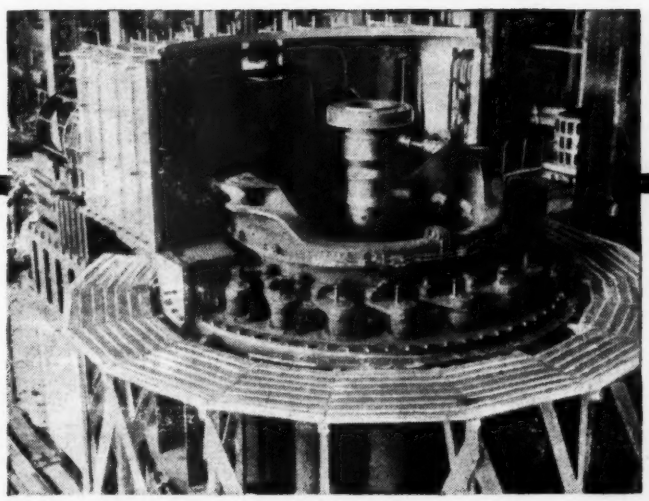

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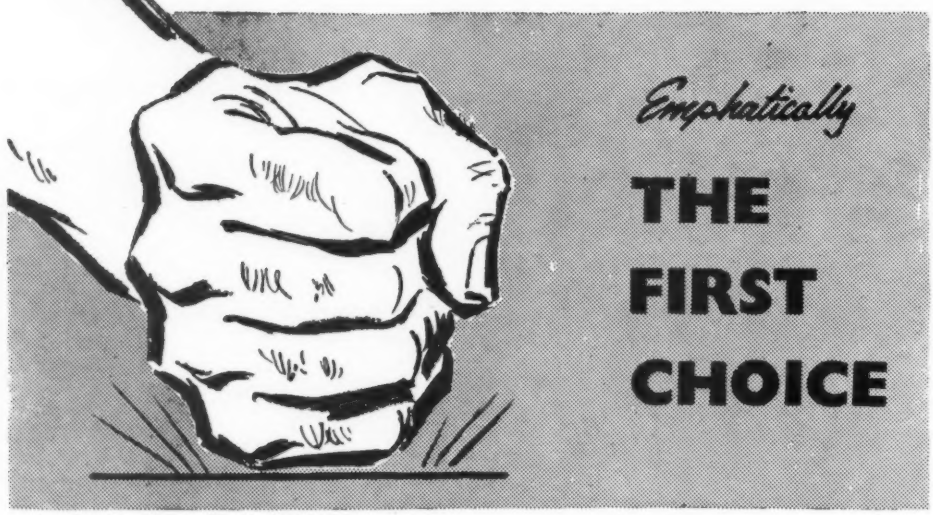

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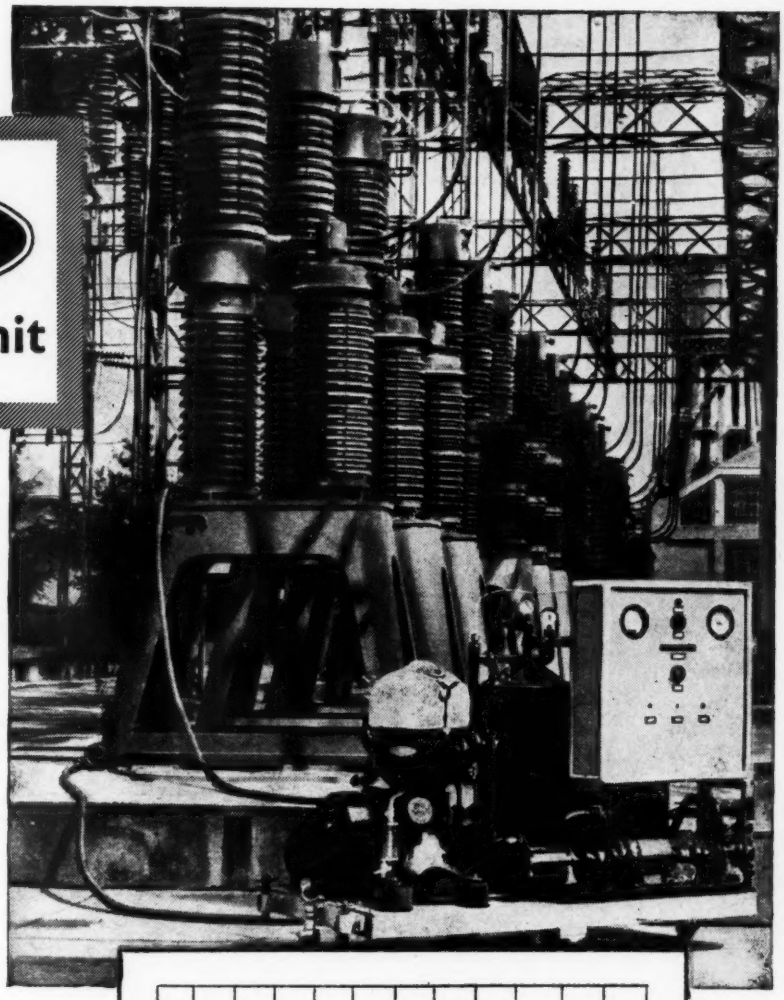

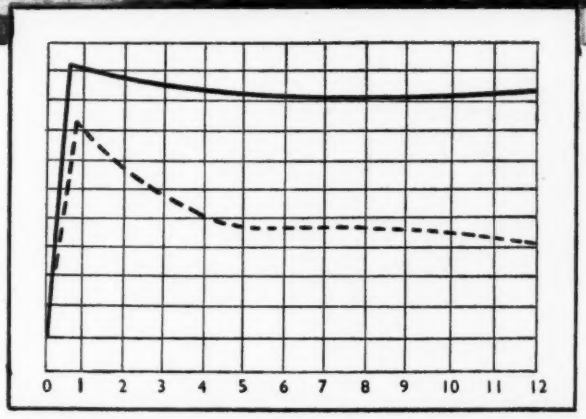

An example of comparative test with two similar transformers operated under the same conditions. The oil in transformer No. 1 was treated by a DE LAVAL High-Vacuum Unit, whereas the oil in No. 2 was purified by means of a filter press. In transformer No. 2 the dielectric strength of the oil rapidly fell off, because the oil was saturated with dissolved moisture, whereas the dry oil in transformer No. 1 retained its high dielectric strength even after 12 weeks' service, when the test was discontinued.

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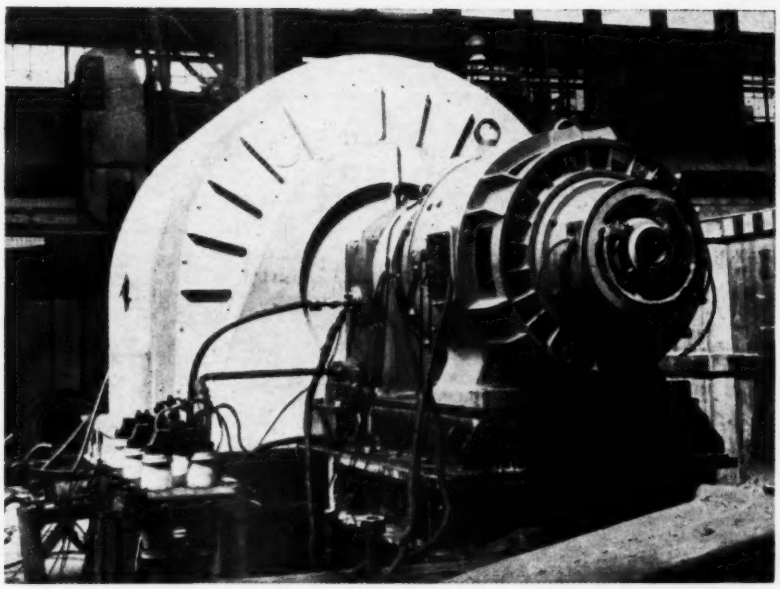

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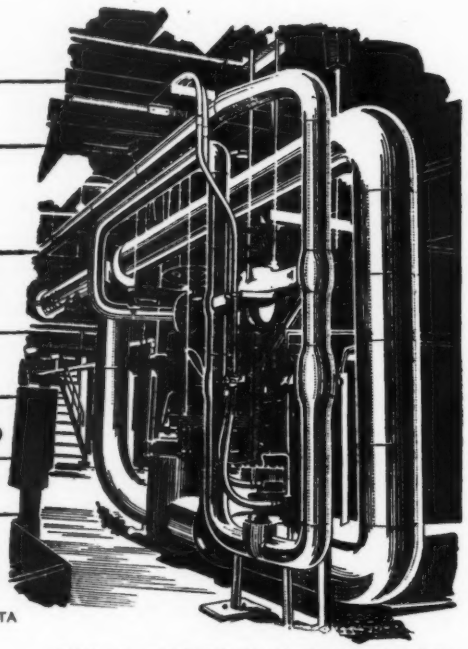

Feed pipework at the boiler feed pumps at Trombay Thermal Power Station

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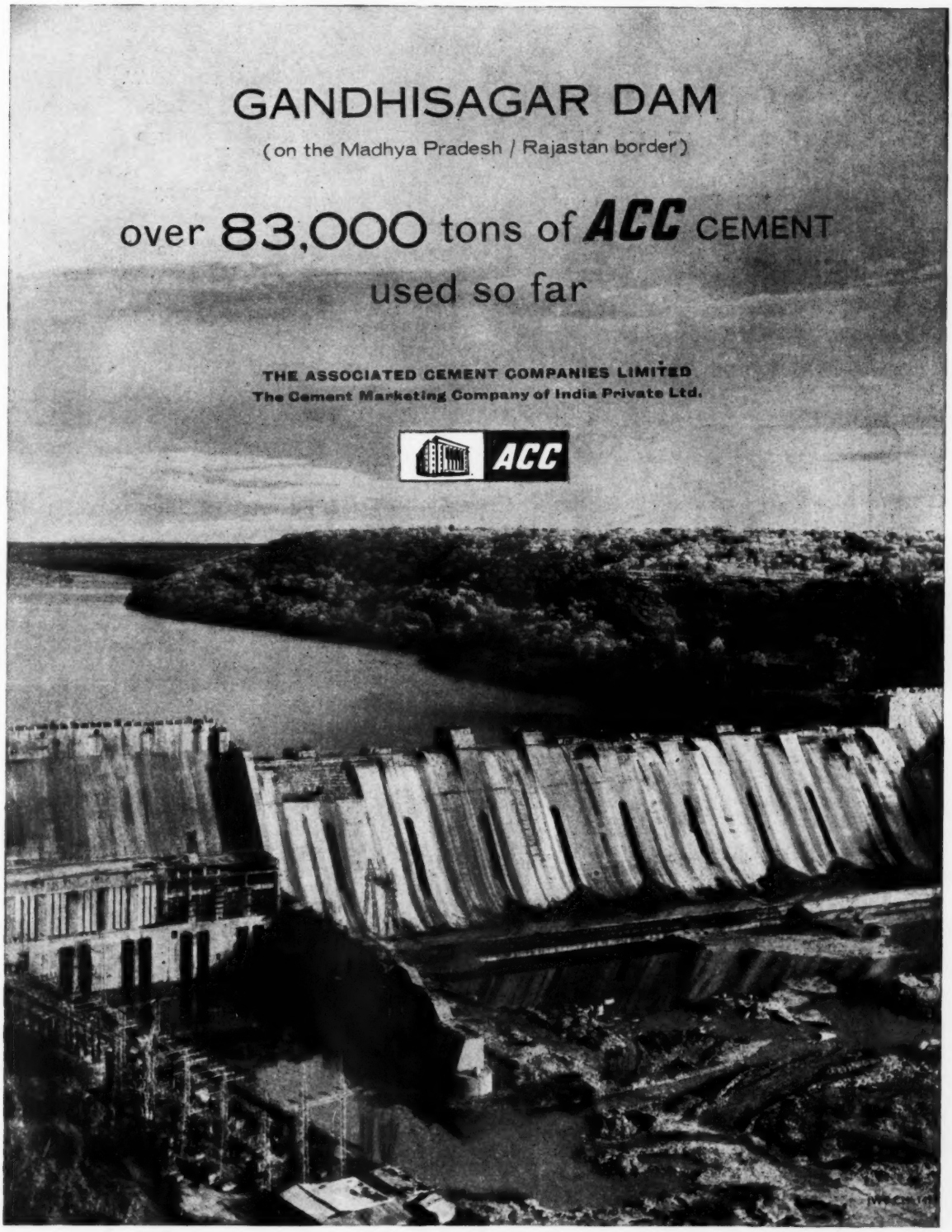
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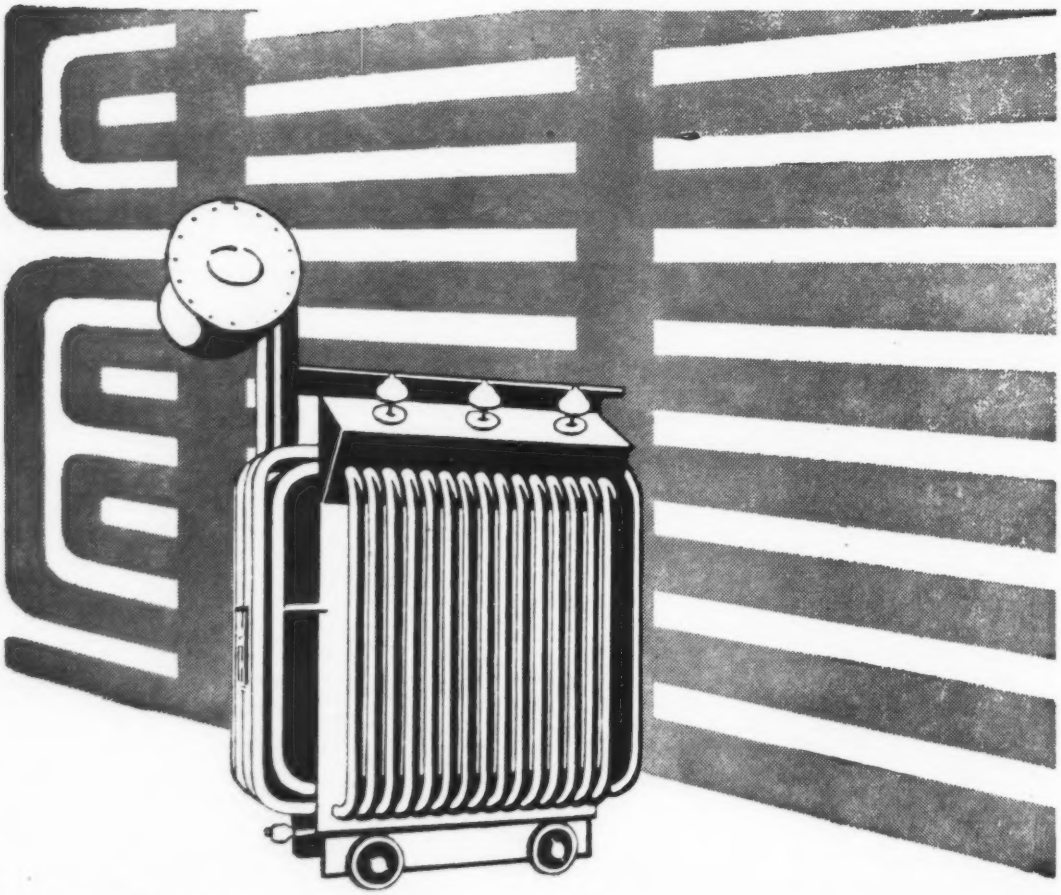

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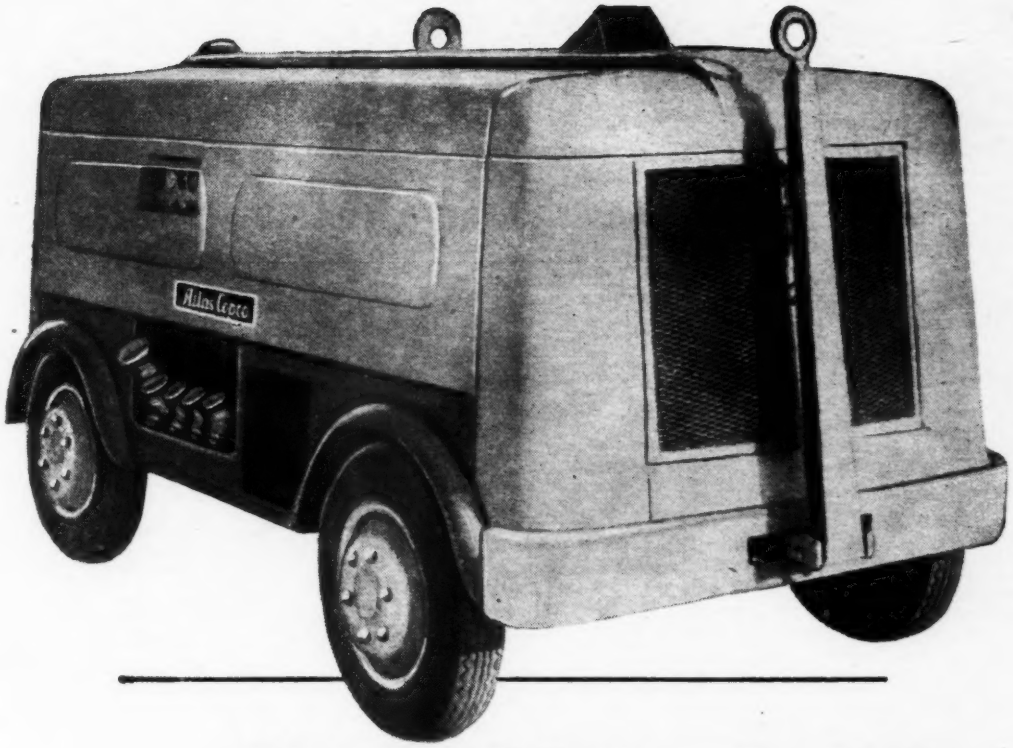

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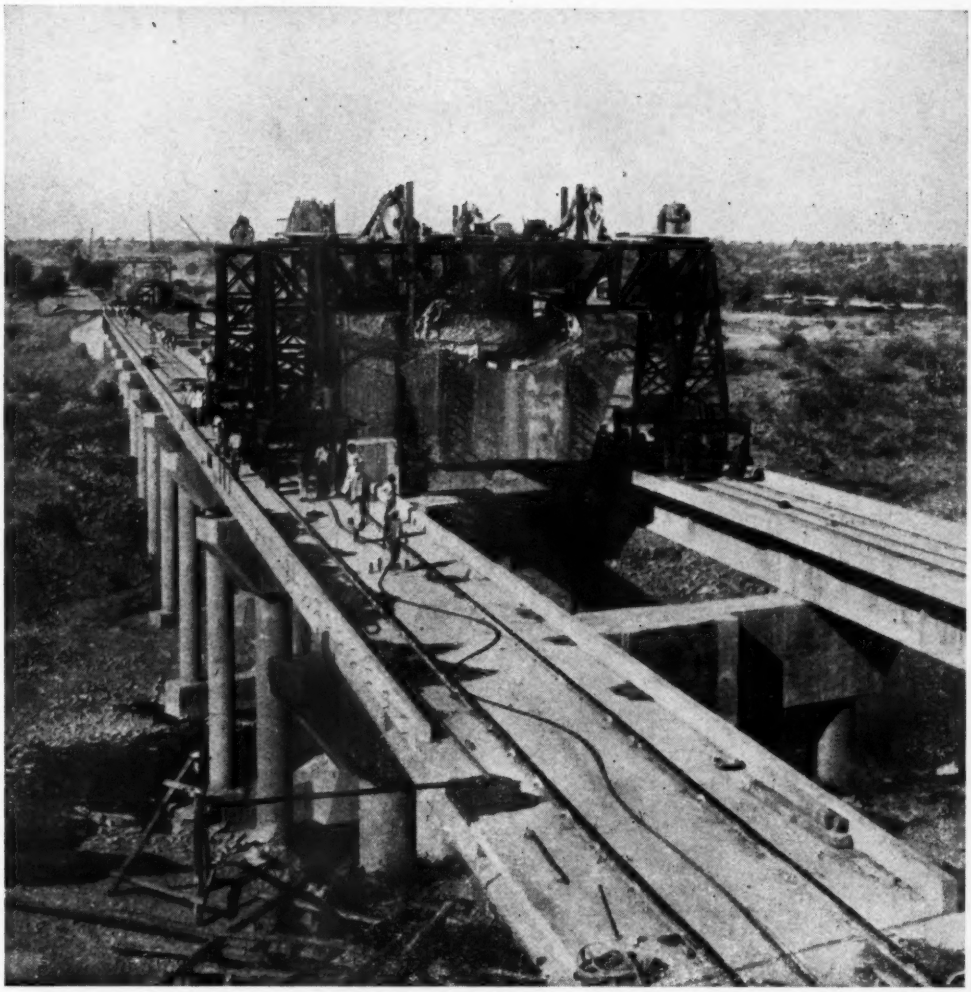

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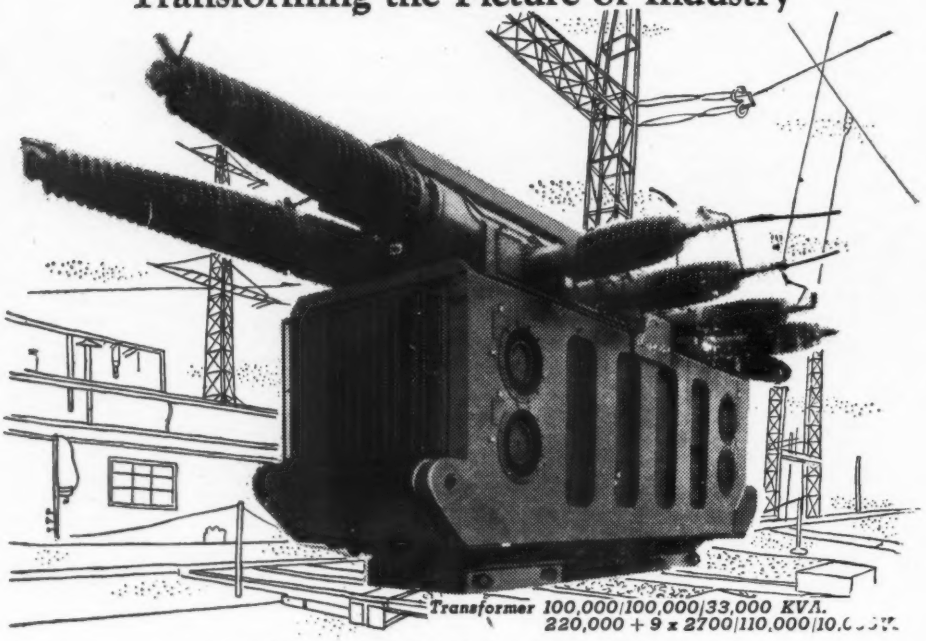

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VOL. X — **OCTOBER, 1960** — **No. 10**

CHAMBAL PROJECT NUMBER

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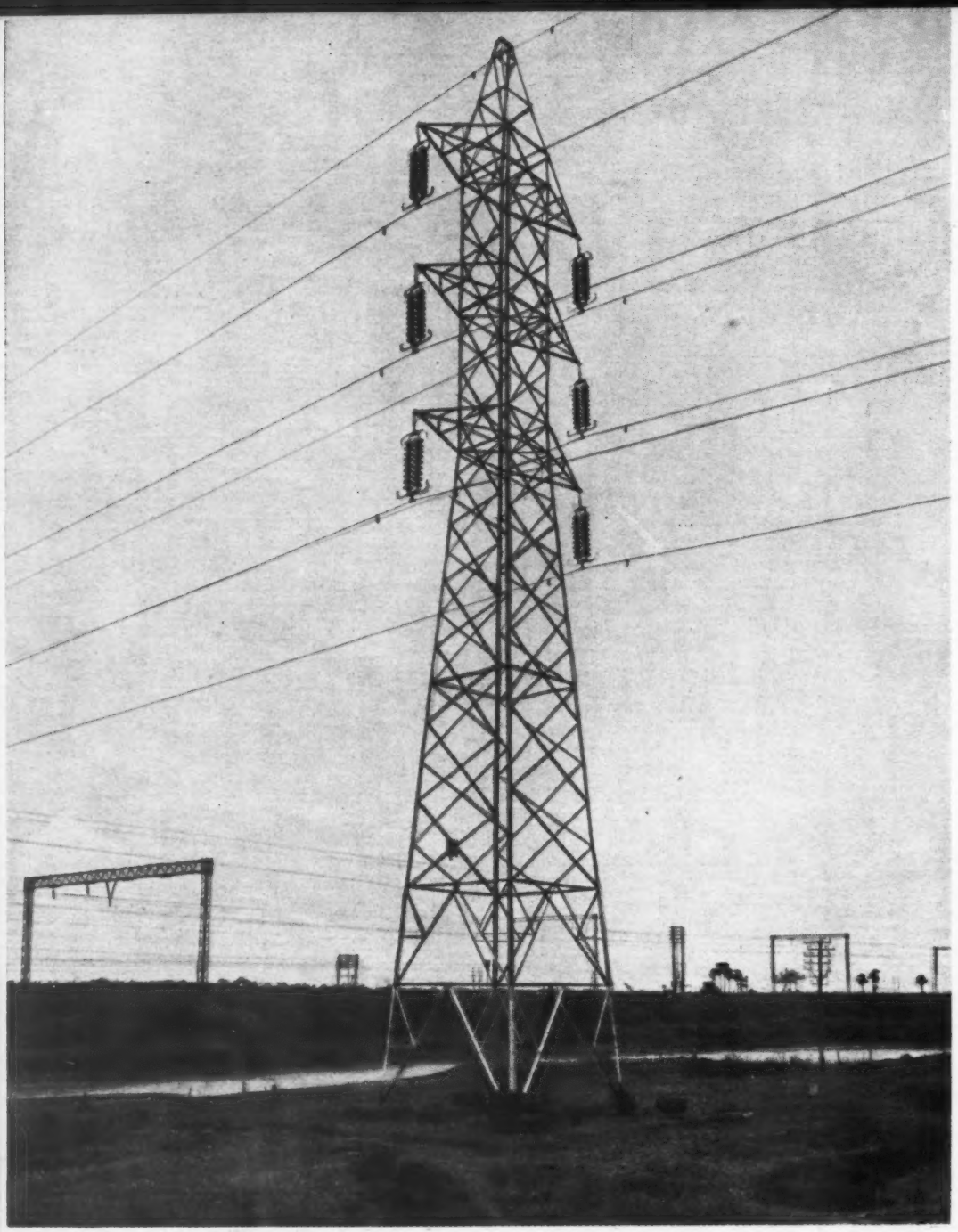

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The Chambal Valley Project is now, more or less, an accomplished fact. Very few people know the initial difficulties which the Project had to face both politically and technically. As I was associated with this Project in my capacity as Central Minister for Works, Power and Mines, I have a clear idea about difficulties through which negotiations had to be carried. I am glad to know that the Chambal Valley Project is, more or less, complete and the flow of prosperity that it will bring to the people of Rajasthan and Madhya Pradesh will start soon. It will give water for irrigation, power for industry and employment all round. The Chambal Valley Project represents the spirit of cooperation between the two States concerned and is a monument of patience, hard work and, I may add, of foresight. I congratulate the engineers and the administration for the success they have achieved. I am also glad to know that progress towards further stages is being rapidly made and that there will be no time-lag between the achievements of various stages.

N. V. GADGIL
Governor of Punjab

I am glad to hear that a special volume is being published on the occasion of the Inauguration of the Gandhisagar Dam which is an event of great significance and marks an important milestone in our progress.

Lack of cheap motive power and proper irrigation facilities are some of the handicaps that have stood in the way of the agricultural and industrial progress of Rajasthan. It augurs well that some of our multi-purpose projects and long term plans are now nearing completion which will provide irrigation for lakhs of acres of uncultivated land, and power for our growing industries thus ushering in general prosperity.

I hope the special volume on the Chambal Valley Project will find a wide circulation.

GURMUKH NIHAL SINGH
Governor of Rajasthan

Messages

The day of inauguration of the Gandhi Sagar Dam is a memorable day for the States of Madhya Pradesh and Rajasthan as large hopes of development of large parts of these two States are based on the successful working of the Chambal Valley Project. The Chambal Valley Project has been a gigantic task in its conception as well as in its execution, and the personnel engaged in its construction have earned the grateful thanks of the peoples of these two States. I congratulate every one concerned with the execution and completion in time of this Project.

H. V. PATASKAR
Governor of Madhya Pradesh

I am glad to know that the *Indian Journal of Power and River Valley Development* proposes to bring out a Special Number on the occasion of the inauguration of the Gandhi Sagar Dam. The completion of the Gandhi Sagar Dam which is included in the 1st Stage of the Chambal Valley Development Project is yet another milestone in this country's industrial and agricultural progress. It is an achievement which has brought credit to the Engineers and workers of the Madhya Pradesh State.

I send my best wishes to the Journal for publishing a Special Number devoted to the Chambal Valley Project.

HAFIZ MOHD. IBRAHIM
Minister for Irrigation and Power
Government of India

It has been my good fortune to be closely associated with the Gandhi Sagar Project ever since 1951 and it has grown up practically before my eyes. I am not an engineer myself but as a lay man, I deeply appreciate the engineering skill which lies behind its construction. Gandhi Sagar Dam is a fitting memorial to the memory of our great leader, Mahatma Gandhi. It will be instrumental in bringing measureless prosperity to the people of Madhya Pradesh and Rajasthan. It will irrigate over a million and a half acres of land and it will illuminate lakhs of homes in the two States. It shall for ever remain as a standing monument to the skill and devotion to duty of its constructors. To them all I extend my heartiest felicitations and greetings.

KAILAS NATH KATJU
Chief Minister, Madhya Pradesh

Messages

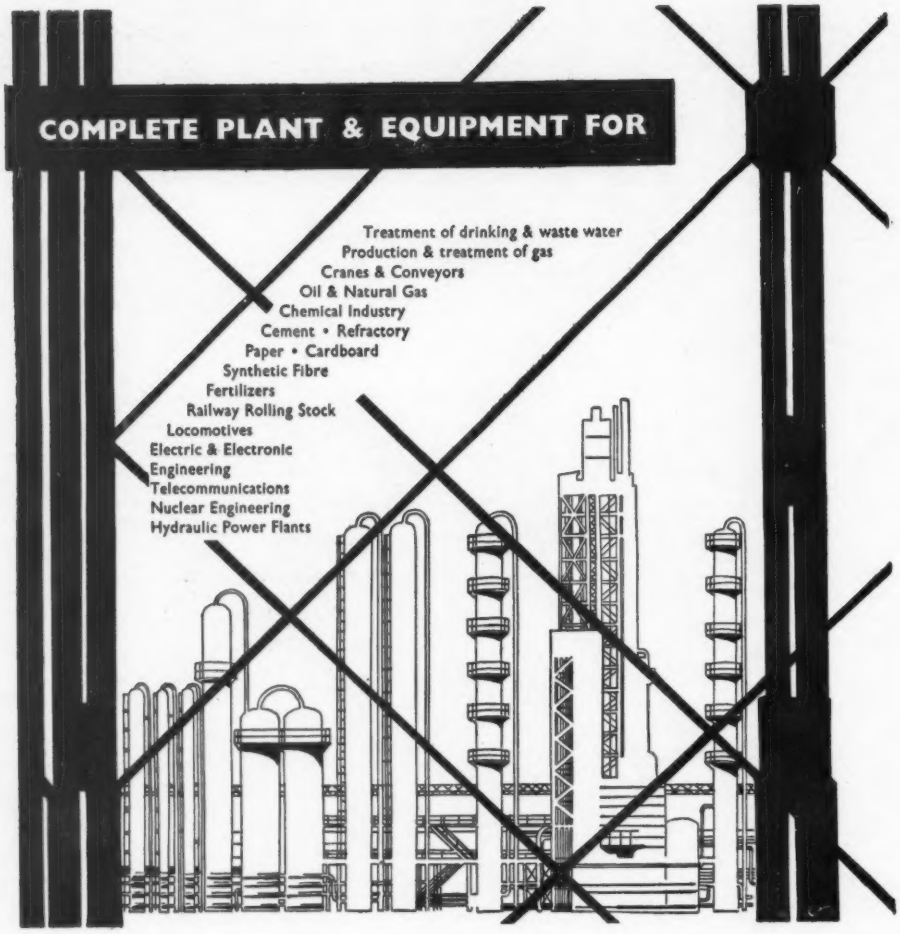
I am glad to learn that a special number of the *Indian Journal of Power and River Valley Development* devoted to the Chambal Valley Project is being published on the occasion of inauguration of the Gandhi Sagar Dam by the Prime Minister. The Chambal Valley Project will bring prosperity to considerable portions of the states of Madhya Pradesh and Rajasthan by making available cheap power and irrigation facilities. It will give a fillip to the agricultural and industrial development of the command-area in the two states and will have an important bearing on their economies. The Project holds great promise for the people in the area.

I hope the special issue of the journal will highlight the special features of the project and will be an informative and comprehensive compilation. I convey through the journal my greetings to the people of the area on this auspicious occasion and wish the publication success.

MOHANLAL SUKHADIA
Chief Minister, Rajasthan

Having been closely associated with the planning and progress of the Chambal Project from the very beginning in the capacity of Chairman, Chambal Control Board, I am happy that the *Indian Journal of Power and River Valley Development* is bringing out a Special Number to commemorate the inauguration of the Gandhi Sagar Dam, which is included in the first stage of the Chambal Project. The completion of the dam will be a landmark in the development of the States of Madhya Pradesh and Rajasthan. It provides a classic example of close co-operation of the two participating States in the planning and execution of the Chambal Valley Project. I would like to extend my congratulations to the engineers and all the workers whose skill and labour have contributed to the successful completion of the dam.

J. L. HATHI
Dy. Minister for Irrigation and Power
Government of India



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SISTA'S-EE-36

INTRODUCTION

The Gandhi Sagar Dam, the first major engineering structure of the Chambal Hydro-Electric Project, covering both Rajasthan and Madhya Pradesh is nearly completed. Thus one of the great steps in developing the two States which had so long remained behind times will have been taken. The modern "temple" of progress in the heart of Central India will have been erected and this will provide fillip to further rapid advancement in many directions. The people of the two States were keenly awaiting this glorious achievement, and now here it is.

It is worthy of notice that given the unique topography and habitation in the area, Gandhi Sagar, the man-made lake created by the Dam, will be the cheapest in the world; the cost of the Dam will be within Rs. 13.6 crores and the storage cost will come to not more than Rs. 20 per acre feet.

The hydro-power that will be made available now will be very much in demand. As a matter of fact both the States of Rajasthan and Madhya Pradesh are developing at such a fast rate that all the power —both hydro and thermal—planned for construction would not be able to cope with the demand by 1965-66. This only indicates the urgency to plan still higher targets of construction in the coming years right from now.

Two special features in the construction of the project needs mention here. Red cement has been one of the major materials used in the Dam; in other words, cement has been combined with 25 per cent pulverised brick powder as puzzolana. This has had no deletrius effect on the Dam while effecting 25 per cent economy in cement. Special and extra-care has been taken in the masonry work.

The other significant feature of the project is the construction of the Kunu Syphon which will be the longest prestressed concrete structure in Asia, with the unique feature of its design of prestressing on Freyssinet system, both circumferentially and longitudinally. The adoption of this latest technique has proved not only economical but has also contributed to easier operation with a minimum labour force.

The Gandhi Sagar Dam is only the first of the three major dams projected under the scheme: the other two are Rana Pratap Sagar and Kotah. We are convinced that when all the major structures are completed, this region, which was so long considered "backward" or underdeveloped, will soon be a healthy rival to other regions in the country. The virility of its people and the vitality of their varied and rich cultures will blossom in their best no sooner they receive the modern scope and facility for their fullest unfoldment under the care and nourishment of these modern 'temples'.

The following contributions, prepared with the collaboration of the Chambal Project Authority will, we hope, provide a comprehensive survey of the magnificent work so far accomplished by the devoted staff and workers of the Project.

This unit will grow

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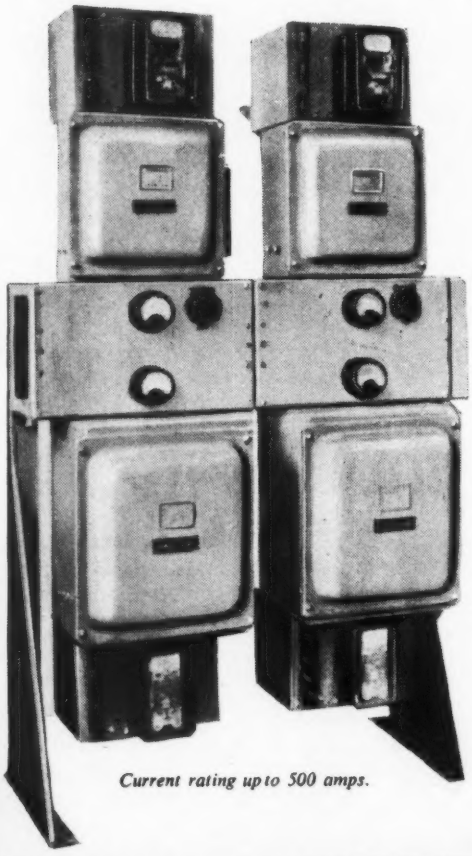
LEADING SWITCHGEAR PROGRESS



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AIC-225

Chambal Water for Prosperity

By A. K. CHAR

THE Gandhi Sagar Dam, which is nearing completion, is the first of the three dams proposed for the development of the Chambal Valley. The other two dams are proposed to be constructed about 24 and 44 miles downstream of the Gandhi Sagar Dam. The Chambal river is a tributary of the Yamuna and drains about 55,300 square miles mostly in Rajasthan and Madhya Pradesh States and a small portion in Uttar Pradesh before it joins the Yamuna river after flowing for a length of nearly 600 miles. This river rises near Mhow and runs for a distance of nearly 200 miles in the districts of Indore, Ujjain, Ratlam, Mandsaur before it enters a gorge near a place called Chowrasigarh situated about 30 miles from Jhalawar Road railway station of the Western Railway. Prior to entering into the gorge section the river in its initial 200 miles length runs in a fairly plain country with an average bed fall of about 3′ per mile. The bed fall of the river increases as soon as it enters the gorge. The river runs for about 60 miles through the deep and narrow gorge and the bed fall of the river in this reach is about 8′ per mile. The river then emerges into the plain again, and runs for another 330 miles before it joins the river Yamuna near Etawah. Here the bed fall of river is 1′ to 1½′ per mile.

The river drains an area of 8,700 square miles by the time it enters the gorge. It drains another 1,900 square miles by the time it emerges out of the gorge. The proposals for the development and utilisation of the waters of the Chambal river at present are confined only to about 10,600 square miles or 19 per cent of the total drainage area of the river. The rainfall in this reach is confined to about 3 to 4 months in the year, July to October, and the rest of the period is practically dry. The maximum, average and minimum rainfall in the year are in the order of 52″, 34″ and 14″, respectively. Thus there is considerable fluctuation in the intensity of rainfall which again is confined to only a brief period of 3 months in the year. During monsoons, the river brings in very heavy floods and practically runs dry during summer months.

The average run off from this 10,600 square miles of the catchment of the river has been computed at about 3.6 million acre feet. The minimum during some years has been as low as about one million acre feet and the maximum has been as high as about 8 to 9 million acre feet. It was, therefore obvious, that for the maximum utilisation of the waters of the Chambal for hydro power generation as well as for irrigation, reservoirs of adequate capacity were an absolute necessity and if the power generation and the irrigation had to be assured of a steady supply, the fluctuations due to the variations in the flow of the river due to seasonal conditions should be tided over by adequate storage.

Keeping all these factors in view, the Gandhi Sagar Dam, the first of the series, with power station has been designed with an effective capacity of nearly double the average annual run-off from the catchment. This was possible on account of the flatness of the basin immediately upstream of the gorge. This basin is a natural cup-like depression 10 to 15 miles in width flanked by high ridges all along, thus forming a unique site for cheap storage. There has been no necessity to construct dykes anywhere to prevent the stored water from by-passing. For a storage of 192′ at the dam which is located 5 miles downstream of the mouth of the gorge, the water spread area is 265.9 square miles or about 1,71,000 acres. Of this area, nearly half is unculturable waste and only about 90,000 acres are under occupation. The gross storage capacity of the lake is 6.85 m.a. ft. making it the cheapest man-made lake in the world. The cost of dam inclusive of acquisition and rehabilitation charges will be within Rs. 13.6 crores or the cost of storage will be about Rs. 20 per a. ft.

The number of people who had to be shifted from the water spread area were about 50,000 and the number of villages (habitations) that were submerged was about 120 and the lands of about 228 villages had to be acquired partially or fully. The intensity of population of this area was not high. It was about 150 per square mile and was a great advantage in so far as the acquisition problems were concerned.

A unique feature that is characteristic of the people of this area is that they are a peaceful and law abiding lot. This has been amply demonstrated by the smooth way in which about 15,000 acquisition cases have been completed in the course of a couple of years with hardly anybody protesting or creating trouble to the organisation. Even though the project adopted labour intensive methods of construction for over six years now, the labour strength going to 10,000 and above during peak working season, the labour relationship was unexceptionable.

The Gandhi Sagar Dam is a straight gravity dam of a maximum height of 214′ above the deepest foundation level, the length of the dam at the top being 1,685′. This dam is constructed of random rubble masonry in what is commonly known as red cement mortar. The term red cement mortar conveys the idea

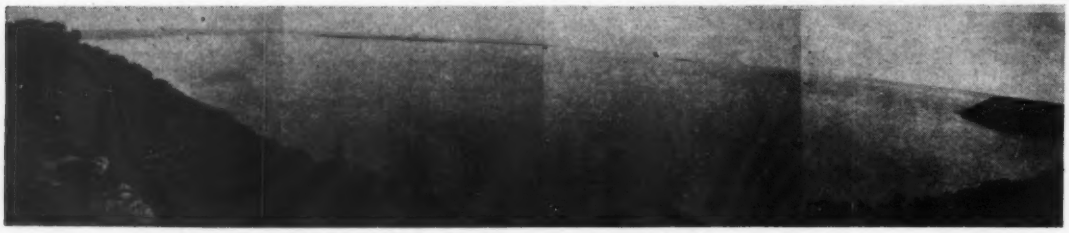


Photo I(a) Waterspread of G. S. Reservoir.

that about 20 per cent of the cement is replaced by finely ground surkhi (brick powder) which is red in colour and hence the terminology. It has been found by experimental observation that the use of this type of mortar for construction will not in any way reduce the strength of cement mortar, ultimately, but on the other hand keeps down the cost and is advantageous where manual laying is employed. The dam consists of 21 blocks as shown in figure. The length of the blocks vary from a minimum of 52′ to a maximum of 100 feet.

The dam consists of three distinct parts:

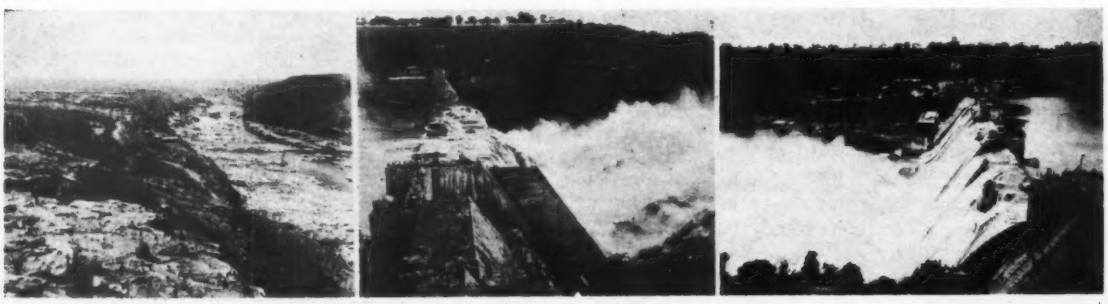
1. Gravity section at the abutments.
2. The spillway section.
3. The power dam section.

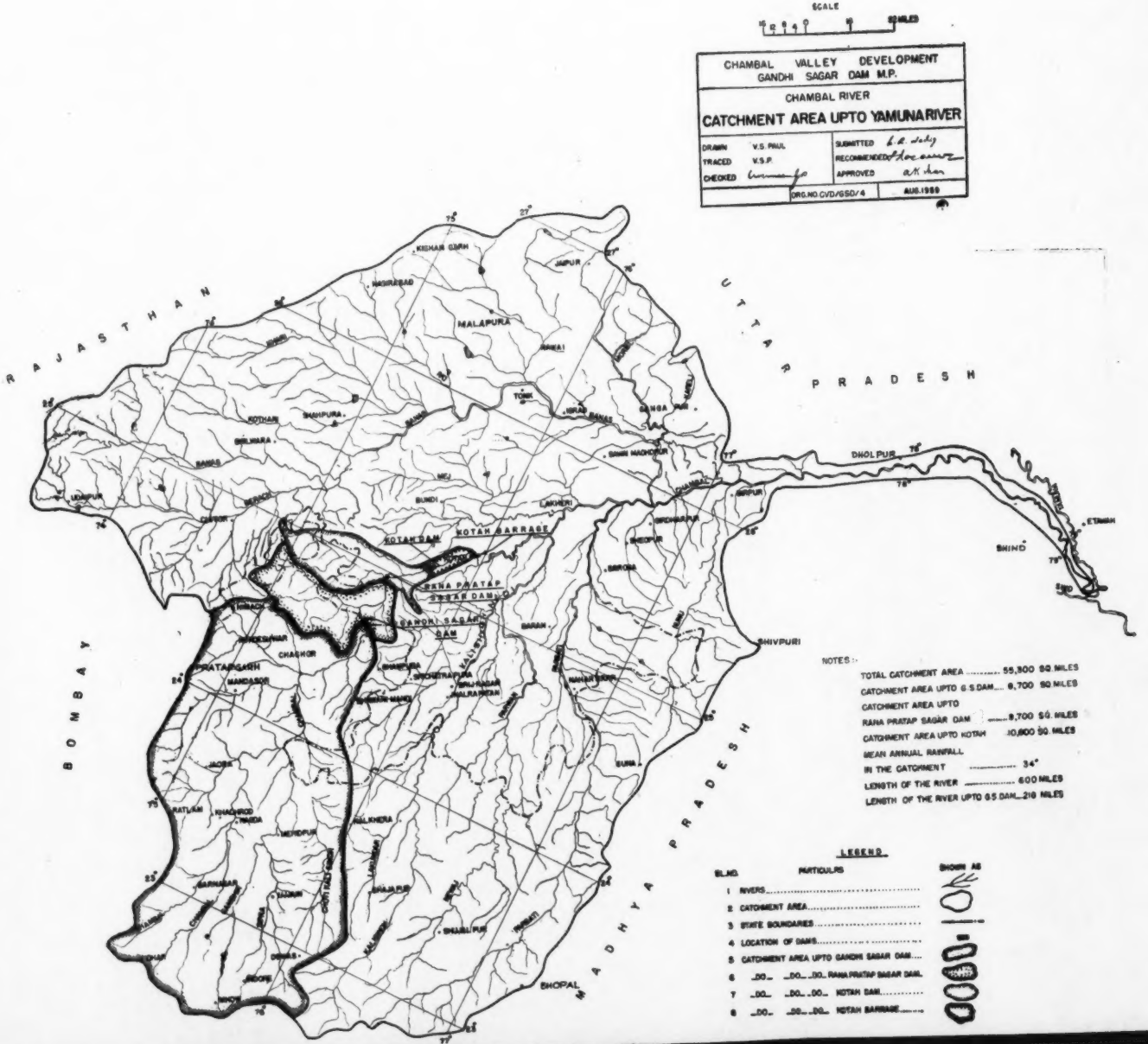
All these sections have been designed on the basis of the standard conventional designs for stability. Gravity blocks have been constructed with hammer dressed stones on the front and rear faces. The spillway block has hammer dressed stone masonry up to the concrete capping level in front and the entire crest and the rear faces are concretefaced including the spillway bucket which is entirely constructed of concrete. In the power block, the rear is of hammer dressed stone and the front up to the trash rack level is of hammer dressed masonry and above the trash rack it is in concrete. The block joints are of two lines dressed stone masonry with shear keys. Special 'U' shaped brazed copper sheet joints are introduced at each block joint embedded in a core of asphalt. At the front face of these block joints, ashlar stone facing is provided. The drainage gallery has been provided right through from one end of the dam to the other at an elevation of 10 to 15 feet above the foundations. Uplift gauges, stress and strain meters, joint meters have all been provided for in the body of the dam to observe the behaviour of the dam. Provision has also been made for the insertion of plumb bobs to observe the deflection of the dam under water pressure.

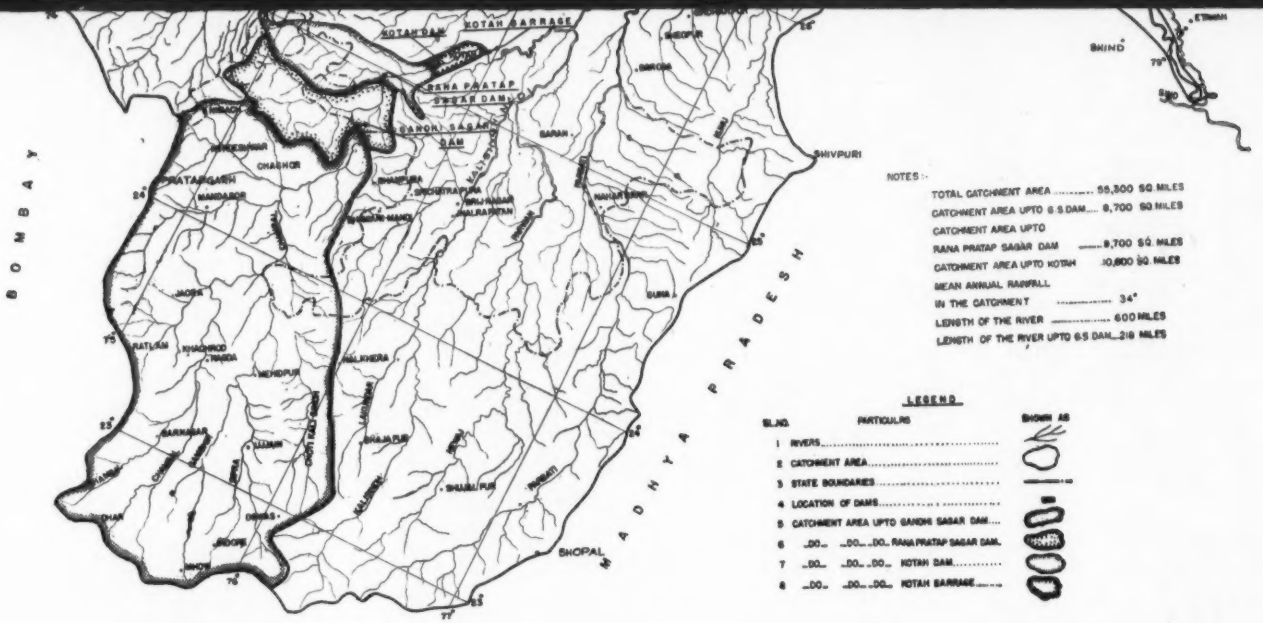
When the Rana Pratap Sagar Dam, which is the next dam downstream, is constructed, the waters of this reservoir back up nearly 40 feet against the rear of this dam. In view of this, a height of 45 feet of the dam has been built in richer mortar $1:2\frac{3}{4}$ proportion similar to the impervious upstream face of the dam. The hearting is constructed of 1:4 in red cement mortar up to about 110 feet above the bed level and above that with 1:5 red cement mortar. Another special feature of this dam is the location of the regulating gates. There are 9 regulating gates of $10' \times 25'$ size. All these gates have been located in the piers between the spillway gates and the piers had therefore to be made sufficiently wide to accommodate these gates. From model experiments this location was found to give the most satisfactory discharge condition when the crest gates as well as the regulating gates are opened simultaneously to pass down floods.

Originally it was proposed to locate two of the regulating sluices near about the river bed level which was however given up on the advice of the Director of the Hydraulic Research Station, Poona, since such

(1) *(2)* *(3)*




SCALE
CHAMBAL VALLEY DEVELOPMENT
GANDHI SAGAR DAM M.P.
CHAMBAL RIVER
CATCHMENT AREA UPTO YAMUNA RIVER
DRAWN V.S. PAUL
TRACED V.S.P.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
ORG.NO.CVD/GSD/4
AUG.1959
N
RAJASTHAN
MADHYA PRADESH
UTTAR PRADESH
BOMBAY
BHOPAL
KISHAN GARH
NASIRABAD
MALAPURA
KOTHAR
SHAHPURA
BIJAIPUR
BANSI
UDAIPUR
CHITOR
BUNDI
TONK
SAWAI MADHOPUR
DHOLPUR
KOTA BARRAGE
KOTA DAM
RANA PRATAP SAGAR DAM
GANDHI SAGAR DAM
CHACHOR
MANDASOR
PRATAPGARH
RATLAM
JHABUA
MEHIDPUR
SHAJAPUR
AGAR
SHIVPURI
ETAWAH
JUMNA
CHAMBAL
NOTES :-
TOTAL CATCHMENT AREA ..... 55,300 SQ.MILES
CATCHMENT AREA UPTO G.S.DAM.... 8,700 SQ.MILES
CATCHMENT AREA UPTO RANA PRATAP SAGAR DAM ..... 9,700 SQ. MILES
CATCHMENT AREA UPTO KOTA DAM 10,800 SQ. MILES
MEAN ANNUAL RAINFALL IN THE CATCHMENT ..... 34"
LENGTH OF THE RIVER ..... 600 MILES
LENGTH OF THE RIVER UPTO G.S.DAM 216 MILES
LEGEND
SL.NO. PARTICULRS SHOWN AS
1 RIVERS
2 CATCHMENT AREA
3 STATE BOUNDARIES
4 LOCATION OF DAMS
5 CATCHMENT AREA UPTO GANDHI SAGAR DAM
6 ..DO.. ..DO.. ..DO.. RANA PRATAP SAGAR DAM.
7 ..DO.. ..DO.. ..DO.. KOTAH DAM
8 ..DO.. ..DO.. ..DO.. KOTAH BARRAGE



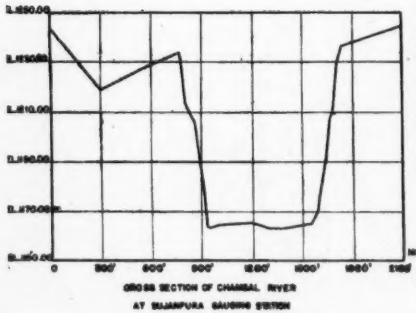
NOTES :-

TOTAL CATCHMENT AREA	58,300 SQ MILES
CATCHMENT AREA UPTO G.S.DAM	9,700 SQ MILES
CATCHMENT AREA UPTO RANA PRATAP SAGAR DAM	9,700 SQ MILES
CATCHMENT AREA UPTO KOTAH	10,800 SQ MILES
MEAN ANNUAL RAINFALL IN THE CATCHMENT	34"
LENGTH OF THE RIVER	600 MILES
LENGTH OF THE RIVER UPTO G.S.DAM	218 MILES

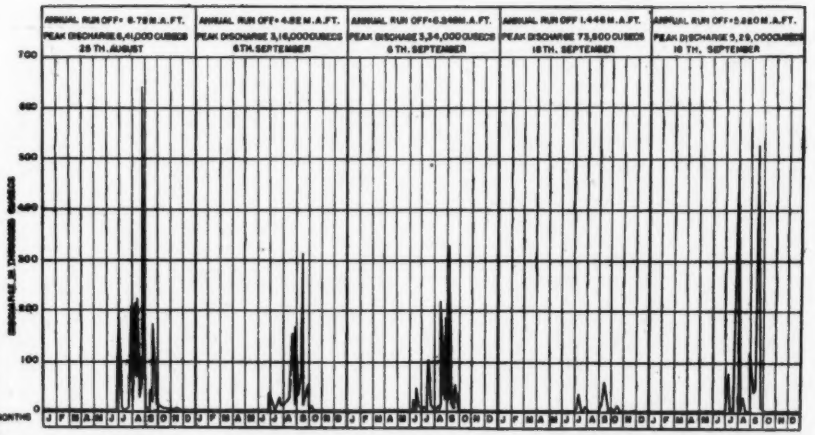
LEGEND

SL.NO.	PARTICULRS	SHOWN AS
1	RIVERS	
2	CATCHMENT AREA	
3	STATE BOUNDARIES	
4	LOCATION OF DAMS	
5	CATCHMENT AREA UPTO GANDHI SAGAR DAM	
6	..DO.. ..DO.. ..DO.. RANA PRATAP SAGAR DAM.	
7	..DO.. ..DO.. ..DO.. KOTAH DAM	
8	..DO.. ..DO.. ..DO.. KOTAH BARRAGE	

0000-10N



GROSS SECTION OF CHAMBAL RIVER
AT SUJANPURA GAUGING STATION



REFERENCES

S.NO.	DATE	TIME	H.F.L.	DISCHARGE IN CUSECS	SHOWN AS
1.	25 - 8 - 1946	2 A.M.	1238·76	6,41,000	
2.	6 - 9 - 1947	4 P.M.	1210·84	3,16,000	
3.	6 - 9 - 1948	7 A.M.	1220·90	3,34,000	
4.	18 - 9 - 1949	10 A.M.	1191·10	73,800	
5.	18 - 9 - 1950	8 A.M.	1234·15	5,29,400	
6.	27 - 7 - 1951	11 P.M.	1203·20	1,85,000	
7.	31 - 7 - 1952	12 NOON	1236·60	4,07,400	
8.	6 - 8 - 1953	5 P.M.	1211·40	2,28,000	
9.	24 - 9 - 1954	10 P.M.	1231·60	4,98,200	
10.	1 - 9 - 1955	11 A.M.	1229·35	4,63,867	

NOTES:-

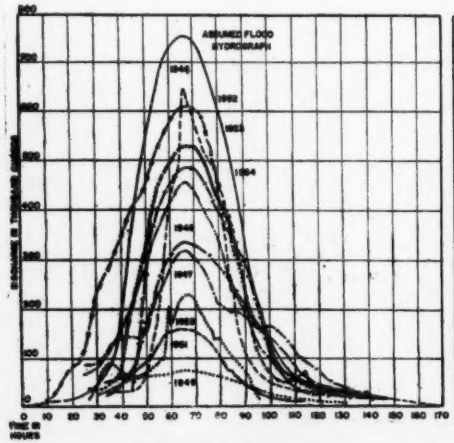
FLOOD DISCHARGES ARE BASED ON THE OBSERVATIONS AT SUJANPURA GAUGING STATION SITUATED 6 MILES UPSTREAM OF THE DAM SITE.

CATCHMENT AREA UPTO DAM SITE = 6,700 SQ.MILES.

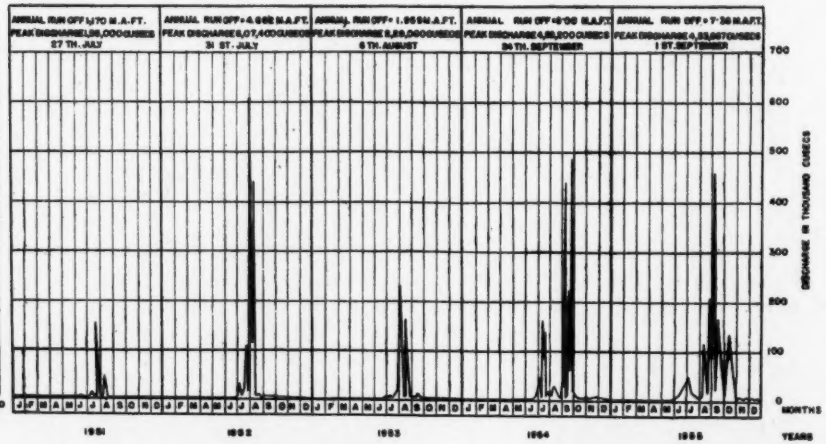
MAXIMUM COMPUTED DISCHARGE BASED ON INGLIS FORMULA $C\sqrt{A}$ = 7,000 $\sqrt{6,700}$ = 6,50,000 CUSECS

MAXIMUM ASSUMED FLOOD DISCHARGE FOR DESIGN = 7,50,000 CUSECS

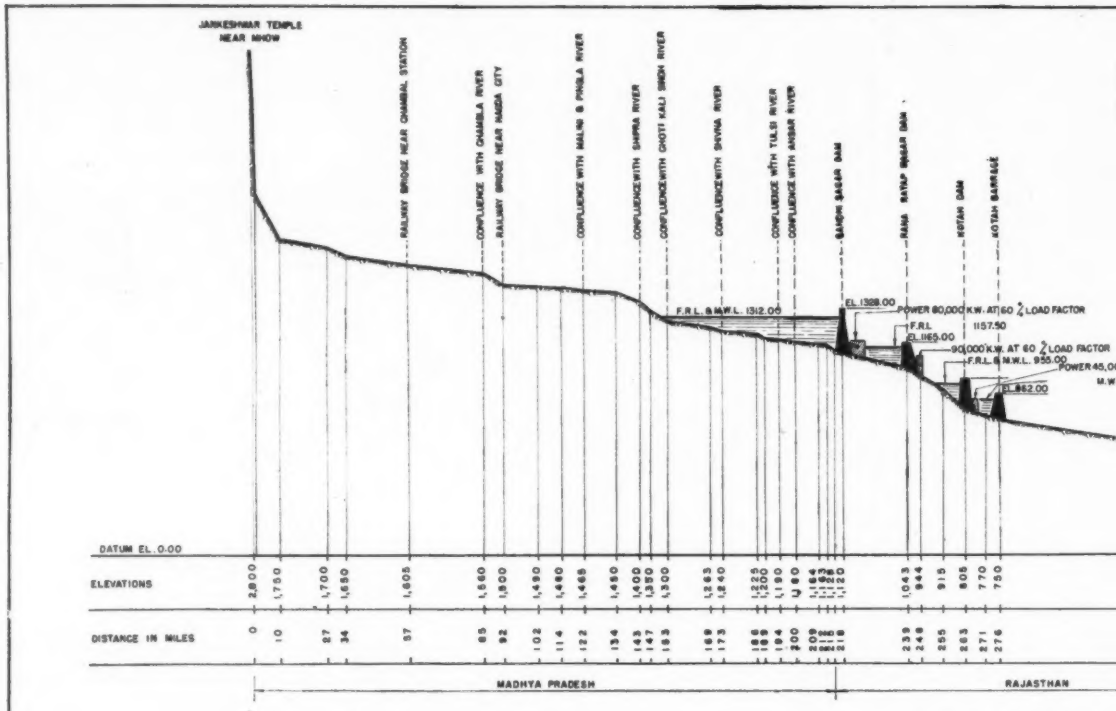
MODERATE FLOOD DISCHAGE ADOPTED FOR DESIGN OF SPILLWAY = 4,50,000 CUSECS



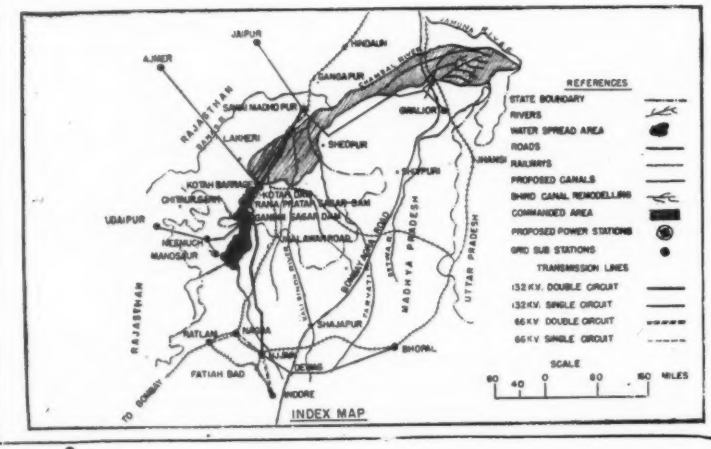
FLOOD HYDROGRAPH OF CHAMBAL RIVER



CHAMBAL VALLEY DEVELOPMENT GANDHI SAGAR DAM M.P.	
G.S.DAM HYDROGRAPH OF CHAMBAL RIVER AT SUJANPURA	
DRAWN V.S. PAUL TRACED V.S.P. CHECKED	SUBMITTED RECOMMENDED APPROVED
DRG.NO. CVD/G.S.D/2	JUL. 1960

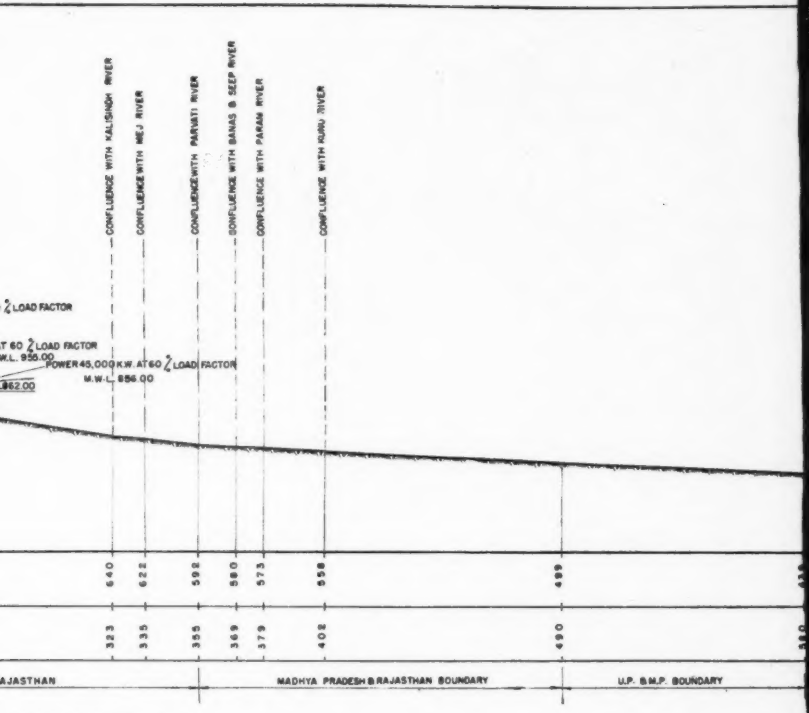

JANKESHWAR TEMPLE NEAR MHOW
RAILWAY BRIDGE NEAR CHAMBAL STATION
CONFLUENCE WITH CHAMBLA RIVER
RAILWAY BRIDGE NEAR RAGDA CITY
CONFLUENCE WITH MALNI & PINBA RIVER
CONFLUENCE WITH SIMPRA RIVER
CONFLUENCE WITH CHOTI KALI SINDH RIVER
CONFLUENCE WITH SIVNA RIVER
CONFLUENCE WITH TULSI RIVER
CONFLUENCE WITH ANSIAR RIVER
GANDHI SAGAR DAM
RANA PRATAP SAGAR DAM
KOTAH DAM
KOTAH BARRAGE
F.R.L. & M.W.L. 1312.00
EL 1309.00
POWER 80,000 K.W. AT 60 % LOAD FACTOR
F.R.L.
EL 1165.00
1157.50
90,000 K.W. AT 60 % LOAD FACTOR
F.R.L. & M.W.L. 955.00
POWER 45,00
M.W
EL 862.00
DATUM EL. 0.00
ELEVATIONS
2,800 1,750 1,700 1,650 1,605 1,560 1,500 1,490 1,460 1,468 1,450 1,400 1,350 1,300 1,283 1,240 1,225 1,200 1,190 1,180 1,164 1,120 1,043 944 915 905 770 750
DISTANCE IN MILES
0 10 27 34 57 65 92 102 114 122 134 145 147 183 189 173 188 188 194 200 209 216 239 248 255 283 271 276
MADHYA PRADESH
RAJASTHAN

LONGITUDINAL SECTION OF CH



CHAMBAL VALLEY DEVELOPMENT (MADHYA

PROJECT	DATE OF COMPLETION	RESU	
		POWER	
1	2	3	
FIRST STAGE		KILOWATTS	
GANDHI SAGAR DAM	1959-60	—	
GANDHI SAGAR POWER STATION	1960-61	80,000	
KOTAH BARRAGE	1958-59	—	
CANAL SYSTEM	1962-63	—	
TRANSMISSION SYSTEM	1961-62	—	
TOTAL		80,000	
SECOND STAGE			
RANA PRATAP SAGAR DAM & BHOPAL POWER STATION & TRANSMISSION SYSTEM		90,000	
TOTAL		90,000	
THIRD STAGE			
KOTAH DAM & POWER STATION		45,000	
TOTAL		45,000	
GRAND TOTAL		2,15,000	



SECTION OF CHAMBAL RIVER

PMENT (MADHYA PRADESH & RAJSTHAN)

	RESULTS		COST IN CRORES
	POWER	IRRIGATION	
	3	4	5
	KILOWATTS	ACRES	
	—	—	13.60
	80,000	—	4.79
	—	—	3.83
	—	11,00,000	30.40
	—	—	10.97
	80,000	11,00,000	63.59
	—	3,00,000	17.21
	90,000	—	
	—	—	
	90,000	3,00,000	17.21
	45,000	—	10.00
	45,000	—	10.00
	2,15,000	14,00,000	90.80

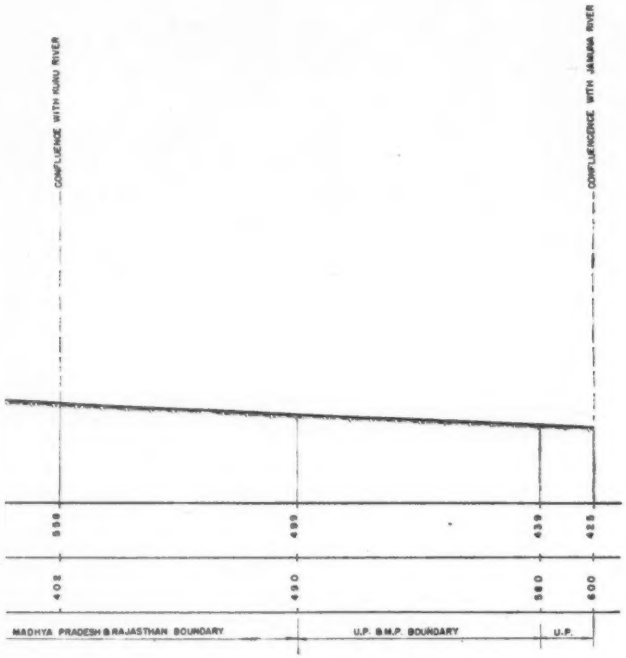
CHAMB

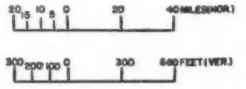
LON

DRAWN

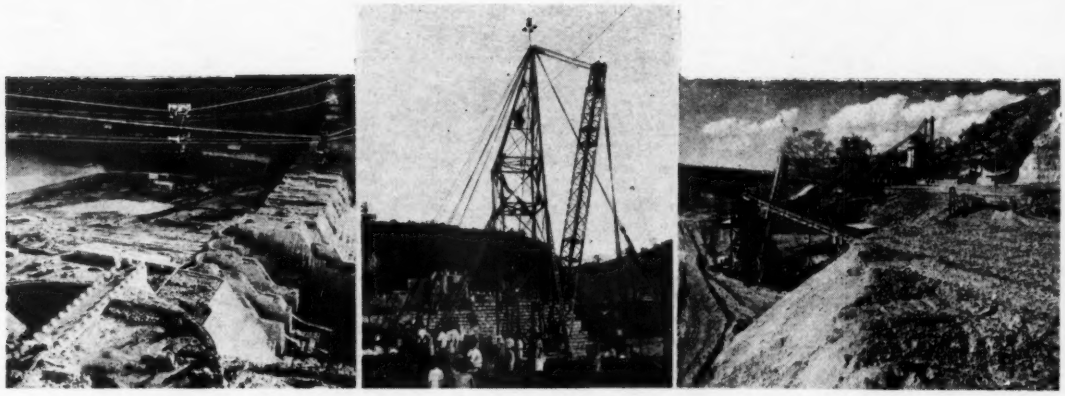
TRACED

CHECKED





CHAMBAL VALLEY DEVELOPMENT GANDHI SAGAR DAM M.P.		
LONGITUDINAL SECTION OF CHAMBAL RIVER		
DRAWN V.S. PAUL		SUBMITTED L.R. Mehta
TRACED V.S.P.		RECOMMENDED Alexander
CHECKED Avenmanjee		APPROVED A.N. Khosla
	DRG.NO.CVD/980/5	AUG. 1960



Illustrations 4, 5 and 4(a)

a location had the possibility of creating disturbed flow conditions.

The construction of the dam in the initial stages was carried out from the upstream side as the dam site was accessible only from that side. Subsequently, as the dam work progressed, access was made from the flanks. Construction materials and particularly concerte were hauled by means of aerial cableways erected at the site.

Inspite of the necessity of carrying construction operations from the upstream of the dam there were certain natural advantages at the site which permitted easy river diversion. Since the river used to bring in discharges in the order of 5 to 6 lakhs cusecs during monsoons, total diversion of the river from the site was not possible. The winter flow however dwindled to less than 2000 cusecs and this could be diverted easily to one side of the river as the river flowed in two distinct channels at the site with a natural ridge in between. The river water was allowed to overflow the masonry of the dam during floods. Care was however taken to provide a construction sluice to discharge about 2000 cusecs which was plugged before effecting storage in the reservoir. Some of the blocks of the dam were kept low to confine the low monsoon flow, so that work could be proceeded on even during monsoons on other blocks by utilising the cableways for hauling construction materials.

The regulating gates of the dam weighing about 35 tons had to be assembled on the dam itself and lowered into the gate slots and there was no possibility of hauling such heavy pieces from the flanks. They had to be inserted into the gate slots to store water at the tail end of the monsoon. The gates were therefore assembled on the top of the dam during monsoons taking all precautions to anchor them down in case the dam overflowed during monsoons. There was heavy overflow over the dam as feared and the gate leafs were all under water, safe in their places. They were subsequently placed in position by a 40 ton travelling gantry specially assembled on the top of the dam for this purpose. All the gates were lowered into position in the course of one month by using this travelling crane. The penstock gates were however lowered into position before monsoon by heavy duty pulley sheaves.

Inspite of the water overflowing the dam and cascading down a hundred feet, not a single stone of the masonry of the dam was dislodged. This itself is a testimony to the excellent quality of work done on the dam. Similarly the seepage through the dam is almost nil and the uplift pressures and temperatures are also well within the assumed limits.

The excellent job, being the very first hydro electric project ever in the States of Madhya Pradesh and Rajasthan has been the result of the devoted and sincere work of thousands of workmen and technical staff drawn from all parts of the country, is today being dedicated to the Nation by its beloved Prime Minister Shri Jawarharlal Nehru.

(Continued from page 7)

GANDHI SAGAR POWER STATION AND THE CHAMBAL GRID SYSTEM

The continued demand for power in the Madhya Pradesh area requires that, in the period between 1961-62 to 1965-66, the Rajasthan and Madhya Pradesh Electricity Boards agree to utilise the total available power to the maximum benefit of the region covered by the Chambal Grid. For meeting the power shortages in both the States in later years, immediate action has to be taken for the installation of the fifth unit at Gandhi Sagar Power Station as well as to expedite the construction of the Rana Pratap Sagar Power Station for commissioning all the four units by 1965-66.

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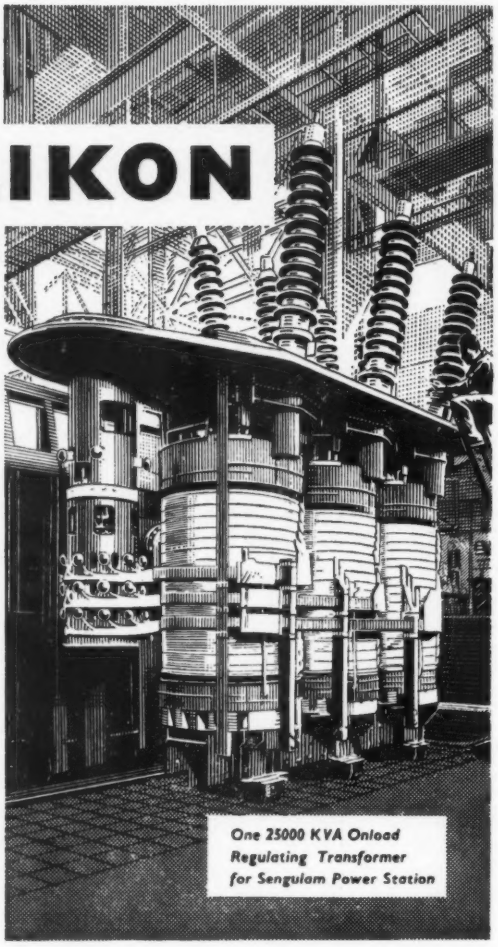

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Gandhi Sagar Power Station and the Chambal Grid System

By K. S. SIVAPRAKASAM

WITH the commissioning of the Gandhi Sagar Power Station in November 1960, the first stage of power development of the Chambal Valley Development Scheme would have been completed. Surveys of transmission lines and construction of the first grid substation was inaugurated in February '57. The first bucket of concrete for the machine foundation in Gandhi Sagar Power Station was laid in October, 1957. The erection of the first transmission line tower was started in October, 1958. By October, 1960, three units of 23,000 kW have been installed at the Gandhi Sagar Power Station, 402 miles of 132 and 66 kV lines have been constructed ready for service, seven grid substations with an aggregate of 132 MVA transformer capacity and the H.V. and L.V. control gear have been erected in Madhya Pradesh at a total cost of 9.58 crores. This is an achievement for any project to be proud of.

The power station is a 311′ long 59′ wide building at the toe of the Gandhi Sagar Dam on the right flank. It houses four Francis type hydraulic turbines of 34,000 BHP capacity each, complete with associated water conductor system in the form of the 15′-6″ diameter, steel penstock pipes embedded in the body of the dam, the scroll casing, the draft tube etc. The steel penstock pipes take off from the upstream side of the reservoir in the form of rectangular bellmouth openings 12′-2.2/5″ wide and 15′-6″ high, gradually transitioned into its circular shape by a series of elliptical configurations in concrete and tapers finally to a diameter of 12′-4″ at the scroll case end. The axial length of the penstock is 130′-8″ and its thickness varies from $\frac{5}{8}$″ at the high pressure sections at the bottom end to 9/16″ at the low pressure sections on the upstream end. After passing through the turbine-scroll casing, the water discharges into the tail race channel through the turbine and the elbow type draft tube extending to such a length on the downstream side that the velocity of the water is reduced to a safe 15.5 feet per second. Each draft tube opening is divided into two sections 10′-8″ wide, and 12′-0$\frac{3}{8}$″ high and is capable of being covered by a draft tube gate 10.8′-$\frac{3}{8}$″ wide and 12′0-$\frac{5}{8}$″ high and weighing about 3.5 tons.

The entry into the penstock pipes is controlled by the 16 ton 12′-2$\frac{1}{4}$″ wide and 18′-6″ high penstock gates, operated by 45 ton hydraulic hoists in the penstock gate operating chamber. A stoplog or emergency gate 16′-2″ wide 26′-8″ high and weighing about 20 tons is also provided in order to facilitate taking out any of the penstock gates for emergency repairs, maintenance, etc., the hoisting being done by the travelling gantry crane of 75 tons capacity with an auxiliary hoisting capacity of 35 tons. The exit from the draft tube is similarly controlled by the two draft tube gates which are operated by a 10 ton gantry crane installed on the downstream side of the power station.

Each turbine is coupled to a vertical shaft umbrella type generator of 23,000 kVA capacity. The turbines and generators for the first three units are of German make, being supplied by M/s. J. M. Voith and M/s. Siemens, respectively, while the fourth unit is entirely of Japanese make, being supplied by M/s. Hitachi Ltd. The Siemens' generators embody certain special features such as the electrical shaft system of excitation, neutral isolation and the magnetic amplifier type of voltage regulation. In contrast to these, the Hitachi unit is provided with the conventional type, directly mounted, main and pilot exciter system of excitation, neutral earthing through a neutral earthing transformer (with a 0.85 ohms resistor in the secondary) and rheostatic type voltage regulator system.

The generators and the step-up transformers in the outdoor switchyard are connected on the unit basis, and 11 kV, 0.6 sq. inch, single core cables carried on trays over a length of about 600 feet of cable tunnel in trefoil formation (with three cables per phase) effect this interconnection. The step-up transformers are single phase type and are rated 7667 kVA. 11/ $\frac{132 \text{ kV}}{\sqrt{3}}$. The L.V. winding is connected in delta and the H.V. winding is connected star with the neutral solidly grounded. These transformers are supplied by M/s. Mitsubishi, Japan.

The switchyard is laid out on the downstream side of the power house, with a duplicate bus bar arrangement and 10 bays at present each 39′ (12 m) wide, to cater for power demands at Ujjain and Kota over independent 132 kV double circuit lines and to Neemuch and Udaipur over a 132 kV single circuit line. The outdoor structures are all of galvanised steel construction and are supplied by M/s. G.I.E., Italy, along with H.V. switchgear, control and protection panels and control desk for the three Siemens units.

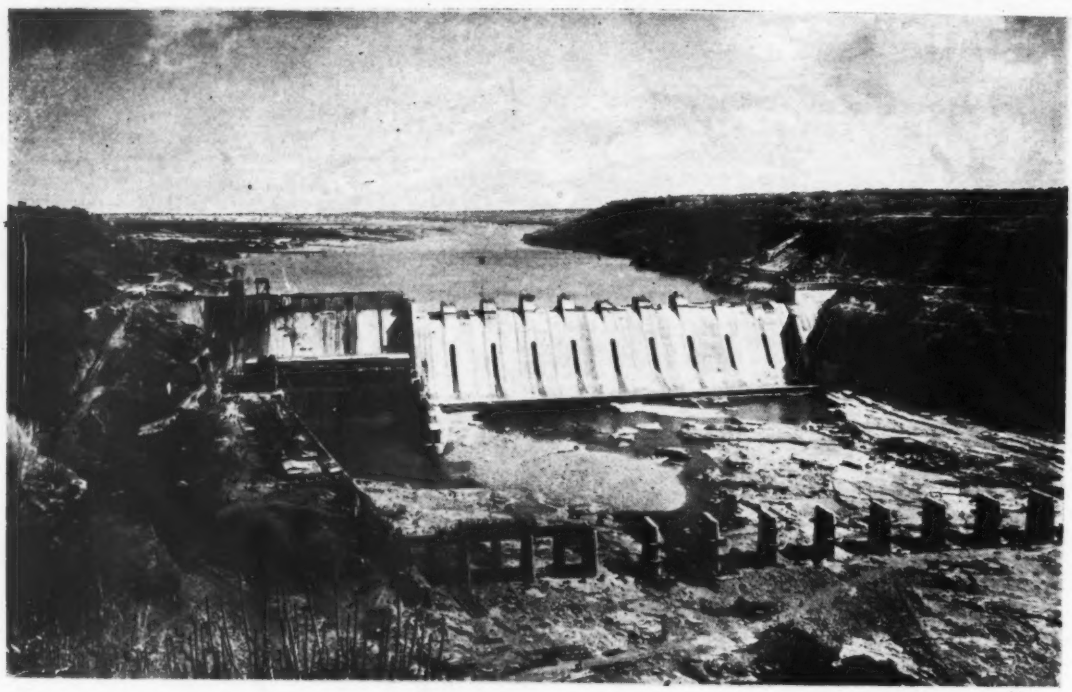

Fig. I—Gandhi Sagar Power Station.

The H.V. switchgear and instrument transformers for the fourth unit are supplied by M/s. Asea, Sweden and the H.V. isolators by M/s. Hitachi Ltd., Japan.

Local power at 11 kV is made available through the two station transformers of 3000/2500/500 kVA, 11/11/0. 42 kV supplied by M/s. Ansaldo San Giorgio of Italy. The auxiliary supply at the power station is made through the secondary windings of these two transformers as well as from a third station transformer of 500 kVA 11/0.42 kV, supplied by M/s. Electroputri, Rumania. Provision has also been made for a fourth station transformer of 3000/2500/500 kVA rating for augmenting the 11 kV local supply.

The transmission system under the first stage of Chambal Valley Development is spread far and wide over the States of Madhya Pradesh and Rajasthan. The schematic layout and capacities of the grid substations, and the transmission system in Madhya Pradesh region are all indicated in detail elsewhere, in this issue. The 132 kV and 66 kV transmission lines carry power to the distant major load centres at Ujjain, Indore, Nagda, Ratlam, Bhopal, Neemuch, Mandsaur and Gwalior in Madhya Pradesh and Kota, Ajmer, Jaipur, Udaipur and Sawaimadhopur in Rajasthan. Figures II, III, IV and V show the Ujjain, Indore, Neemuch and Mandsaur Substations in different stages of construction.

To meet the increasing demands for power in this area, the existing major thermal power stations at Indore, Bhopal, Chandni, Jaipur and the proposed thermal power stations at Jodhpur and Sawaimadhopur are proposed to be inter-connected with the Chambal Hydel Grid .

With the installation of the 5th unit at Gandhi Sagar Power Station and the completion of the Rana Pratap Sagar and Kota power stations in the II and III stages, with $4 \times 32{,}000$ kW and $3 \times 26{,}000$ kW units respectively, the ultimate installed hydro-capacity in this area would be 321 MW and the firm power available would be 240 MW at 60% load factor, i.e. 80 MW at Gandhi Sagar, 95 MW at Rana Pratap Sagar and 65 MW at Kota Power stations.

Summarising, the power resources in the Chambal

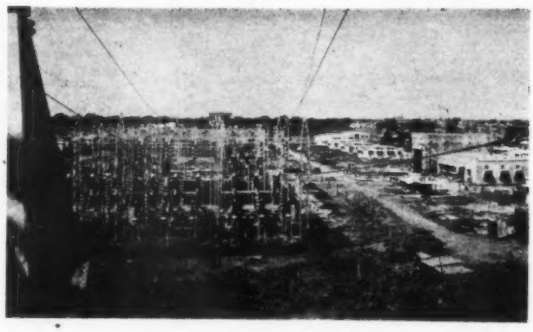

Fig. 2—Ujjain Substation.

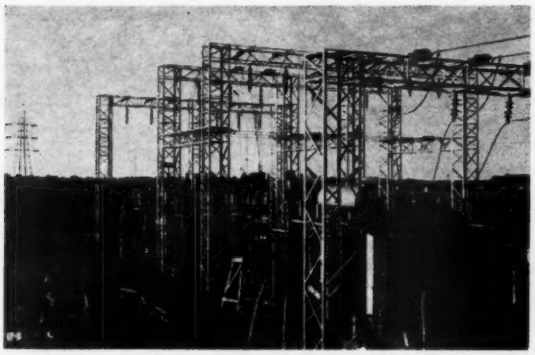

Fig. 3—Indore Substation.

Area which could be depended upon to meet the load requirements of the Madhya Pradesh and Rajasthan regions are as follows:—

		1961-62	1965-66	1970-71
Gandhi Sagar, Rana Pratap Sagar, Kota	Hydro	80.0	175.00	300.00*
Sawaimadhopur	Thermal	—	60.0	120.0
Jaipur	Thermal	8.0	8.0	8.0
Jodpur	Thermal	—	9.0	9.0
Indore	Thermal	10.0	10.0	10.0
Bhopal	Thermal	7.5	7.5	7.5
Chandni	Thermal	17.0	17.0	17.0
	(a)	122.5	286.5	471.5
	(b)	105.5		

* *Note:* Additional peaking capacity of 60 MW available at hydro-stations due to the Sawaimadhopur thermal station operating at 120 MW and 90 per cent load factor.
(a) Assuming that Chandni-Chambal interconnection will be completed by 1961-62.
(b) Assuming that Chandni-Chambal interconnection will not be completed by 1961-62.

As against this, the anticipated power demands of the two States (as per the preliminary report of the Central Water and Power Commission for Network Analyzer studies of the Chambal Grid System) are as follows:—

		1961-62	1965-66	1970-71
Madhya Pradesh	(a)	93.4	164.4	264.0
	(b)	73.2	—	—
Rajasthan		23.5	177.3	310.0
TOTAL	(a)	116.9	341.7	574.0
	(b)	96.7	—	—
Thus deficit/surplus	=(a) plus	5.6	−55.2	−102.5
	(b) plus	8.8		

It is observed from the above statements that the available power resources in this area are adequate to meet the anticipated demands upto 1961-62 only and thereafter the shortage of power begins to be felt. A break-up of the deficit/surplus in the two States indicates that during 1961-62 Rajasthan will have a surplus of 24.5 MW while Madhya Pradesh faces a deficit varying from 18.9 MW to 15.7 MW, depending on whether the Chandni interconnection is effected or not by that time. In 1965-66 Rajasthan has also a deficit of 12.8 MW while Madhya Pradesh's deficit increases to 42.4 MW and in 1970-71 the deficit in both the States reaches 23.0 MW and 79.5 MW respectively.

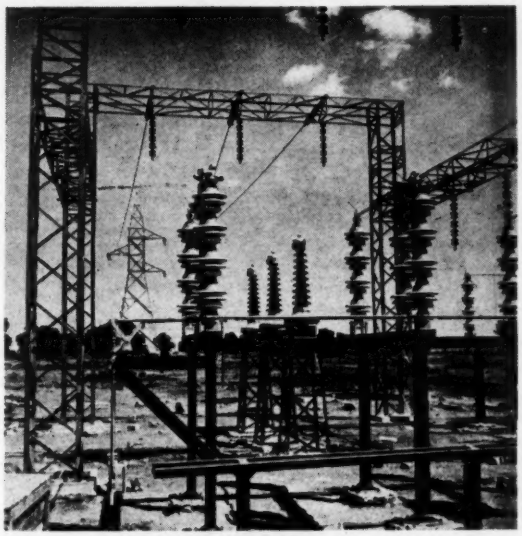

Fig. 4—Neemuch Substation.

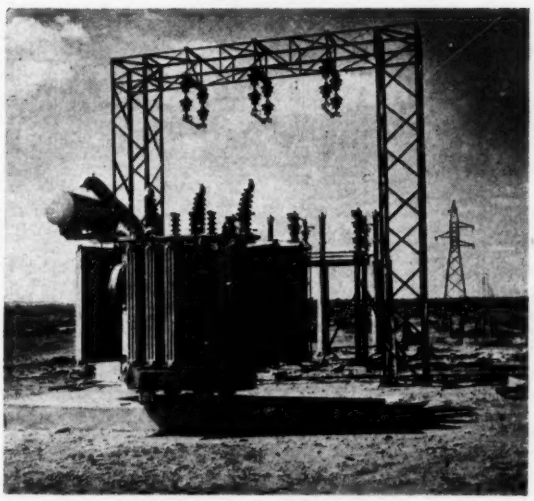

Fig. 5—Mandsaur Substation.

(Continued on page 3)

GANDHI SAGAR DAM

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Construction Features of Gandhi Sagar Dam

By S. RANGANNA

EVEN in the Princely States of the Central India, prior to their merger, a hydel-cum-irrigation project on the river Chambal had been considered by the old Holkar State. The project was sited, about 1½ miles downstream of the Chourasigarh, in the narrow gorge through which the Chambal is flowing. After the merger of the States into Madhya Bharat and Rajasthan, the location of the dam was shifted downstream by another 3½ miles where better advantages could be had.

RIVER AND CATCHMENT

The Chambal River takes its source near Mhow on the northern slopes of Vindhya Range. This river is one of the main tributaries of the Yamuna which itself is a tributary of the Ganga. The river by the time it reaches the gorge will have descended from elevation 2,400 at its source to elevation 1,160. The river travels about 50 miles in the narrow gorge varying from 600′ to 2400′ in width. The sides of the gorge are about 300′ and more above the bed level. To the site of the dam the river drains an area of 8700 sq. miles with an average rainfall of 34″.

Flow and discharge

The Chambal is a rain-fed river. The prevailing monsoons in the area is the South-west, which lasts from the middle of June to the beginning of October. In this area almost whole of the rainfall is confined to this monsoon period and there are very few showers in winter. The flow in the river also follows the rainfall pattern, discharging heavy quantities of water during the monsoon and dwindling away and almost drying up before the break of the next monsoon. In view of these characteristics any development of the river has naturally to depend upon the storage created for the purpose. A study of the rainfall and the catchment indicates an average yield of 3.5 million acre feet of water. In the years of heavy rainfall the yield will be much more and while in the years of low rainfall the yield will be very much less. To make the available water equitably over several years, the reservoir capacity has been fixed to allow a carry over capacity from good years to bad years.

The catchment area of the river is made up of black trap overlain with fertile soil. A study of the gorge shows shales overlaining quartzite and dripping slightly towards the downstream of the river. At the present site of the dam the bed of the river is an exposed sheet of quartzite rock estimated to be more than 200′ in depth. The dam site is free from any faults. Only the rock is formed in layers interlain with thin soft materials. The rock is very abrasive but suitable to withstand the stresses that are imposed upon it by the construction of a dam. The gorge is narrow. The combined requirements of an adequate spillway and power station has made it obligatory to discard the narrowest part of the gorge in preference to the present site.

DESIGN AND LAYOUT OF THE DAM

The structure is designed as a straight gravity dam. The length of the dam is divided into a number of blocks capable of acting independently. The dam is designated as 'Spillway Dam', 'Power Dam' and 'Non-spillway Dam' according as it is required to dispose off the floods, or house the penstocks etc. of the power portion or staunch the structure to the sides of the gorge without the water overtopping it. The dam section is designed for a maximum stress of 15 tons per sft.

The uplift is allowed to act on the 2/3rd of the base area with an intensity equal to head water on the heel and the tail water on the toe. The river is known to discharge very heavy floods during the monsoons. In fact the flood marks on the sides of the gorge indicate that floods of an intensity of 5 lakhs cusecs and above are not uncommon. The design takes into considerations a maximum flood of 7.5 lakhs cusecs. To provide for this intensity of flood a certain amount of flood absorption capacity of the reservoir has been made use of. The surplussing arrangements provided consist of an overflow dam controlled by 10 crest gates of 60′ × 28′ deep and 9 regulating sluices, each 10′ × 25′. The flood discharge through these surplussing arrangements will be 4.5 lakhs cusecs after taking 10 per cent of the discharging capacity as not available. The important dimensions and levels of the various sections of the dam are as under:—

	Non-overflow section	Overflow section	Power section	Sluice section
(a) Batter Front	1:13	1:16¼	1:13	1:16¼
(b) Rear	7.1:10	6.7:10	7.1:10	6.7:10
Width at top	21 ft.	—	30 ft.	40.5 ft.
Maximum width at bottom	164.21 ft.	175.67 ft.	164.21 ft.	175.67 ft.
Maximum height above foundations	204 ft.	171 ft.	204 ft.	209 ft.

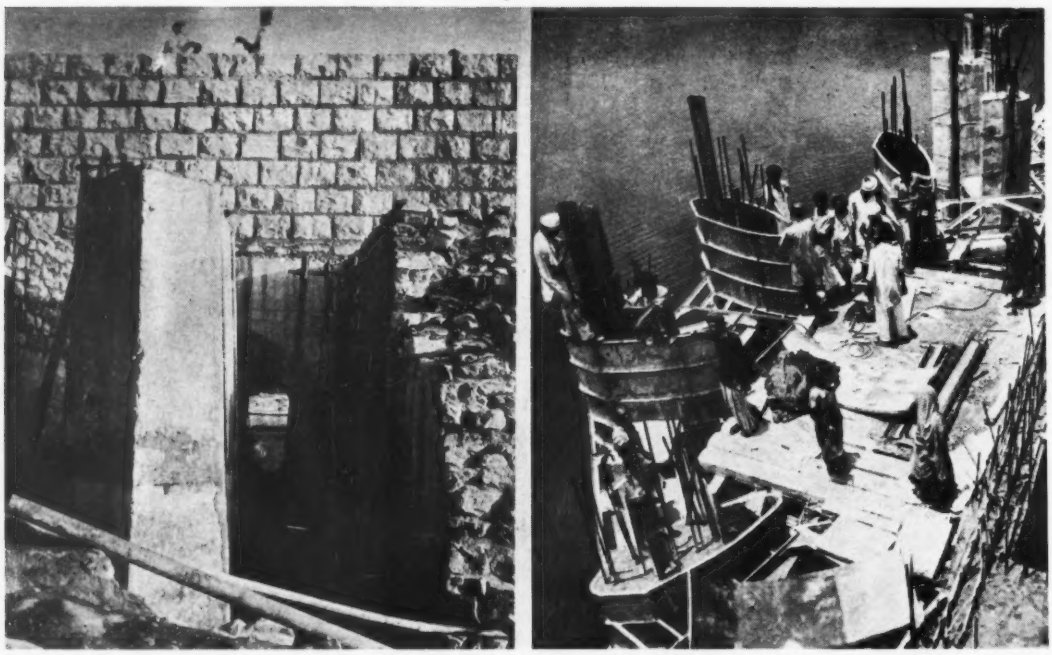
Reservoir levels:

Average bed level of river	...	El. 1120.00
Road on top ...	...	El. 1324.00
Top of parapet ...	...	El. 1328.00
Centre line of sluices ...	...	El. 1206.00
Crest of overflow ...	...	El. 1284.00
Full reservoir level ...	...	El. 1312.00
Maximum water level ...	...	El. 1312.00
Dead storage level ...	...	El. 1250.00
Centre line of penstocks	...	El. 1205.50

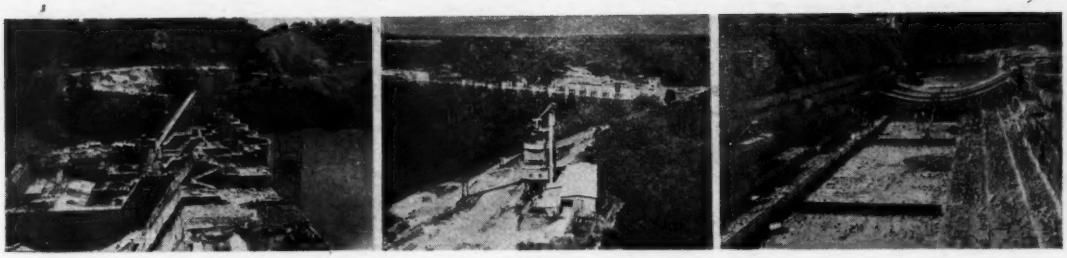
DIVERSION OF THE RIVER DURING CONSTRUCTION

As the river discharges huge quantities of water only during the monsoons, it will be uneconomical to provide diversion works for the total diversion of the monsoon floods. As the maximum discharge has been observed to occur any time during the monsoon, the period available for the construction purposes can be only about 8 to 9 months. In view of this the diversion proposals were made only for the post monsoon flow of the river. A study of the bed contour of the river at the dam site shows two distinct channels of flow on account of the narrow spur on the left half of the river. Taking advantage of these spurs a low masonry coffer dam was thrown between the right bank and the spurs. This coffer dam was kept low when the work of excavation was going on, as an unexpected spill over the coffer dam was no serious hindrance. With the completion of the excavation between the spur and the right bank, construction was taken up and the river on the left side was further restricted to a narrow portion and the excavation of the left bank taken up. The construction of the right half was raised to the bed-level and the river's post monsoon flow was diverted over a low portion of this construction and the untackled portion of the bed was taken up for excavation for the foundations. With the completion of the excavation, masonry was raised throughout the width of the river. As the construction proceeded, to obviate the inconveniences, low coffer dams were raised to heights sufficient to rule out the spills in the post monsoons. With the progress of the construction, the diversion of the post monsoon flow was provided by a construction sluice in block No. 4. As the name itself indicates this is only a temporary opening left through the body of the dam, to be plugged up at a convenient stage later. This sluice was in sections of 20′ length. The water end of each length being 12′ wide and the narrow end 10′ wide on the downstream end of the 20′ section. The sluice was covered over by a semi-circular arch. This converging section helps the concrete to tightly plug itself with the water load in the front.

With the advent of the construction of the power dam, penstocks have to be buried in it; the upstream end of the penstocks have to be closed by control



LEFT TO RIGHT: *Construction sluice in block No. 4 and the semi-cylinder walls on u/s side and the cellular walls on d/s side of the power house.*



LEFT TO RIGHT: *Semicellular walls on u/s side and cellular walls on d/s side of the power-house, the batching plant and the form work for the spillway bucket.*

gates. As this will not be possible until the gate chambers, etc., are ready, water from the river has to be prevented from flowing through these penstocks into the power station area. The raising of the dam raises the flood levels on the upstream side and any structure proposed to prevent the flow of water through these penstocks will consequently be high. On account of these the section of the coffer dam in front of the penstocks become very massive. In the Gandhi Sagar Dam 5 penstocks are provided. These penstocks open out into the reservoir with suitable transitions. These transitions were enclosed by semi-circular walls of 2′ thickness These walls raised to a height of 60′ formed a semi-cylinder and kept out very heavy floods. The power station is susceptible to floods from the downstream side as well, on account of the draft tubes of the turbines. On the downstream side of the Gandhi Sagar Power Station a cellular wall had been built in the draft channel to keep out the flood from the river downstream of the dam.

EXCAVATION FOR FOUNDATIONS

The river bed consisted of a sheet rock, sides rising by about 40′ in steps towards the bank. Throughout, the sides of the gorge are precipitous and almost vertical. In view of this there was little overburden in the river bed. In the flanks, in addition to the overburden of hard murrum, disintegrated rock and depths of laminated rock had to be removed for exposing proper foundations for the dam. On account of sheet rock the excavation in the bed necessitated opening out a trench. This trench was then gradually widened out to the required width of the dam foundations. On account of the formation of the rock in layers even in the flanks, blast holes of great depths were found to be of little use. The holes for the blasting purposes were drilled 2′ to 4′ and rarely more than 6′. The whole of the excavation was made by using gelatine of 60 per cent strength and hand-blasting. After the top layers of the stable rock were blasted and removed the final levels were reached by controlled blasting. The depth of the holes was always kept to a maximum of 2/3rd of the depth that had to be removed. After the excavation with the use of explosives were completed, the foundation trenches were cleared of all loose rock and softer formations by chiselling. Wherever exposed foundation was smooth, on account of laminated formations of the rock, the surface was chiselled for roughening.

FOUNDATION TREATMENT

On account of extensive blasting that is required to get at the foundations the possibility of rock layer down below the foundations being disturbed, cannot be ruled out. Such effects on the foundations due to blasting are to be rectified. In the Gandhi Sagar Dam the whole of the foundation area, after excavation was laid out in regular pattern for low pressure grouting. The low pressure grouting consolidates the foundations into a mass. All the holes in the pattern are drilled up. The holes are then washed by using water and air under pressure. During the process of cleaning the holes of the pattern may get interconnected. The washing of the holes is continued until the affluent from the holes is clear. After the washing is completed the grouting is commenced. The cement grout is prepared and kept agitated to avoid the settlement of the cement. This grout is drawn and injected into the cleaned holes by the use of a piston pump preferably working on compressed air. As the grouting continues the water, collected in the seams underground, will be displaced by the grout, which finds its way out as clear water through several holes. On the continuance of grouting the holes begin exuding grout and when the grout escaping from a hole is very nearly of the consistency of the grout being injected, the holes are plugged up by wooden plugs. Successively other holes of the pattern as will be ready for plugging will be closed and all the connected holes are plugged up. The pressure of the grout will then begin to increase and the grouting will be stopped when the stipulated pressure is maintained. When the grouting is completed the cock on the grouting holes is closed and the grout injected is allowed to set for a period of two to three days. The plugs of the several holes are then removed and all the holes are redrilled and washed off and the holes are tested again for tightness. Such of the holes which

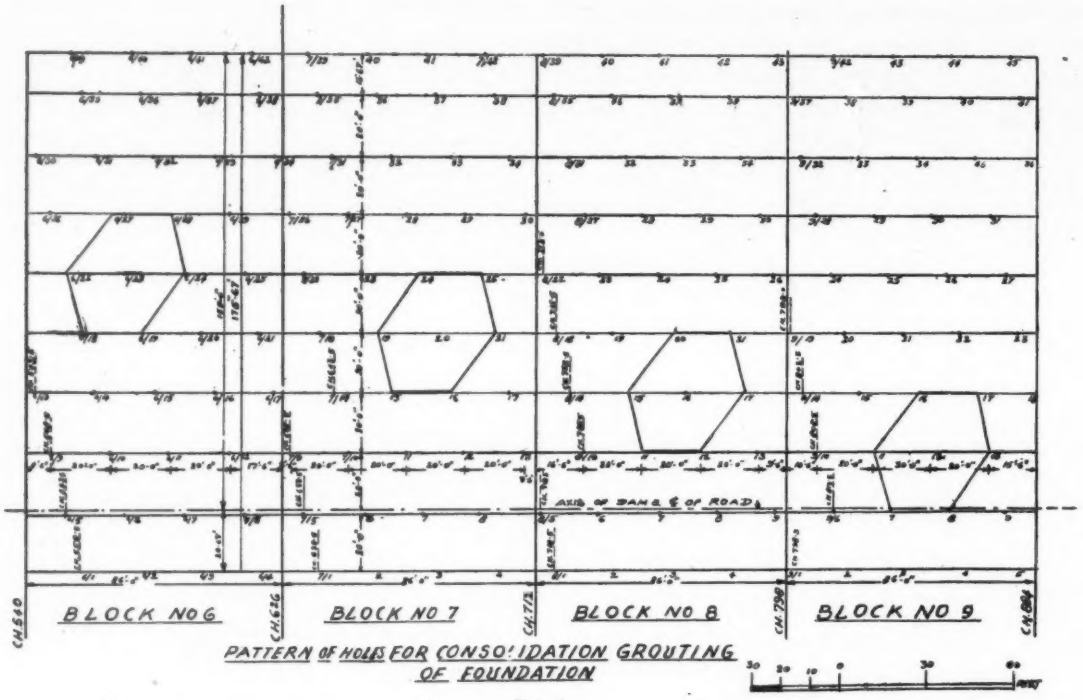


Fig. 1

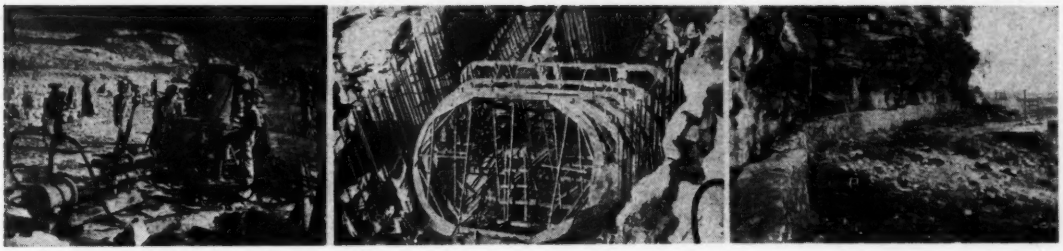
are tight will be locally plugged by cement grout and others will be subjected to injection again. This process continues till the holes refuse to accept any more grout.

The consolidation grouting is meant only for a shallow depth. The water of the reservoir accumulating on the upstream of the dam may get connected up through vertical seams to horizontal layers far below the consolidated layer and begin to escape on the downstream side. In doing so the reservoir water will exert an uplift pressure on the base of the dam and also form a flow channel for the loss of water from the reservoir. To prevent these normally one or two lines of grout curtains are introduced below the dam about the heel region. Curtain grouting is a process of introducing an impermeable barrier of cement grout from the bed level to a good depth below the foundation of the dam. The holes for these are, to begin with, drilled to partial depth at larger intervals. These holes are washed, tested and grouted with pressures more than 75 lbs per square inch. After the grout in these holes are set, they are drilled and washed. Further drilling will be continued through the rock in the same holes, and grouted again. Holes in between the original holes will also be drilled and grouted. The behaviour of the intermediate holes will give a clue as to the necessity of drilling more holes in between these. This is grouting by split spacing and will be found useful as it indicates the behaviour of the strata and the effectiveness of the grouting. Curtain grouting is always to be taken up after the foundation is loaded by the dam to prevent possible lifting up of the rock. In Gandhi Sagar Dam curtain grout holes of $1\frac{7}{8}$″ diameter have been drilled 100′ to 150′ depth at intervals of 8′. The first line of curtain grout is provided from the upstream of the dam. The holes are located at about 10′ from the upstream edge of the dam and drilled inclined up to about 10° to the vertical towards the dam.

To begin with a 2″ diameter hole is drilled to a depth of about 2′ in the required inclination. In this hole a 3′ to 4′ pipe of equal diameter is grouted. This stem pipe is necessary (1) to guide the drill rods and (2) to screw in and hold in position the grouting manifold against the enormous pressure that will be applied.

SEALING UP OF OPEN SEAMS

The vertical sides of the valley meet the bed, rising in steps from 1120 at about E.L. 1165 and 1170. This junction is not tight but reveals an open seam varying in width from 6″ to a couple of feet. By probing, it has been found that this open seam continues back for a considerable distance into the flank. The reservoir water standing about 150′ high above this seam necessitated the rendering of this potential outlet water-tight. Along the front face of the dam the grout curtain had intercepted this seam. However, the possibility of this seam outflanking the dam and connecting



LEFT TO RIGHT: *The grouting apparatus, form work and reinforcement for the draft tube, and the sealing of the open seams.*

the reservoir to the downstream side could not be ruled out. One ready solution thought of was to fill up this open seam by masonry for a considerable distance upstream and then inject cement behind this masonry thus sealing it out. The cost of this operation was prohibitive. Clay is a good stoppage for percolation. It also will be soft under water and continue to be fed into the seam by the water load. Due to these two characteristics, it was proposed to plug the seams with clay.

A masonry wall 2′ wide was built along the open seam leaving a 2′ clearance between it and the precipice. The open seam was then cleaned up of all removable material as far inside as one could get at. Well kneaded clay was then filled in the channel thus created and pushed into the seams and filled up. The space between the precipice and the wall was then filled up with further clay to the top of the wall and was kept quite wet and plastic till the break of the monsoon. This treatment was made on both the right and the left banks of the valley upto a distance of about 500′ on the upstream of the dam. Now the water level standing at 110′ above the seam has not shown any percolation through it to the downstream side.

DRAINAGE SYSTEM

As already mentioned previously the water in the reservoir will be exerting uplift pressure on the dam. This is to be avoided as far as possible to get the full advantage of the mass of the dam. The curtain grouting will have done away with much of the uplift pressure by sealing off connecting seams between the reservoir and the bottom of the dam. Even if any seams escape they will produce a certain amount of uplift action. To prevent this uplift, drainage holes of diameter 3″ to 4″ are drilled to depths of 40′ to 50′ into the foundation of the dam from the drainage gallery bed and will be inclined towards the downstream. These holes will be drilled only after all the grouting operations are over. These open holes will serve as pressure releasers to the bottom of the dam. In Gandhi Sagar Dam 3″ diameter holes are drilled at about 20′ intervals.

Under the spillway bucket also a drainage system as indicated in the drawing is provided. Every block of 86′ length is provided with 3 headers into which drainage holes open out. These headers are interconnected by laterals to embedded pipes which discharge to the atmosphere.

MASONARY

Gandhi Sagar Dam is mainly built of stone masonry. All the exposed faces over which water will not flow are built with hammer dressed stone masonry. The hearting in all the places is of random rubble. For the masonry the rubble specified is of a minimum weight of 80 lbs free from cracks, weathered surfaces, thin flaky layers, etc. The object being that sound stone is only used. The stone used for the Gandhi Sagar Dam is hard quartzite very abrasive and weighing about 160 lbs per c.ft. The crushing strength of the stone is 15,000 lbs per sq. inch.

For the masonry of Gandhi Sagar Dam red cement is used. Red cement is Portland cement mixed up with 25 per cent of the puzzolana, which in this case is pulvarised brick powder (Surkhi). This addition of surkhi powder to Portland cement has no deleterious effect on the ultimate strength. On the other hand ultimate strength will still be much more than what is neded and 25 per cent economy would have been achieved. This red cement is also a slow setting and a low heat cement. On account of its property of low heat the shrinkage cracks, while mortar cools after it is set, will also be minimised. In Gandhi Sagar Dam mortars of proportion as given in the table below have been used. The mortar is made up of the red cement and natural sand in various proportions and is mixed in concrete mixers. Free water, as determined after taking into consideration the moisture content of sand, is only used. The table indicates the proportion of mortar and places where it is used.

(i) Front impervious face from axis of dam to upstream face.	Red cement mortar (Red cement: sand 1 : 2¾ by volume.
(ii) From 100′ downstream of axis to rear face of dam	-do-

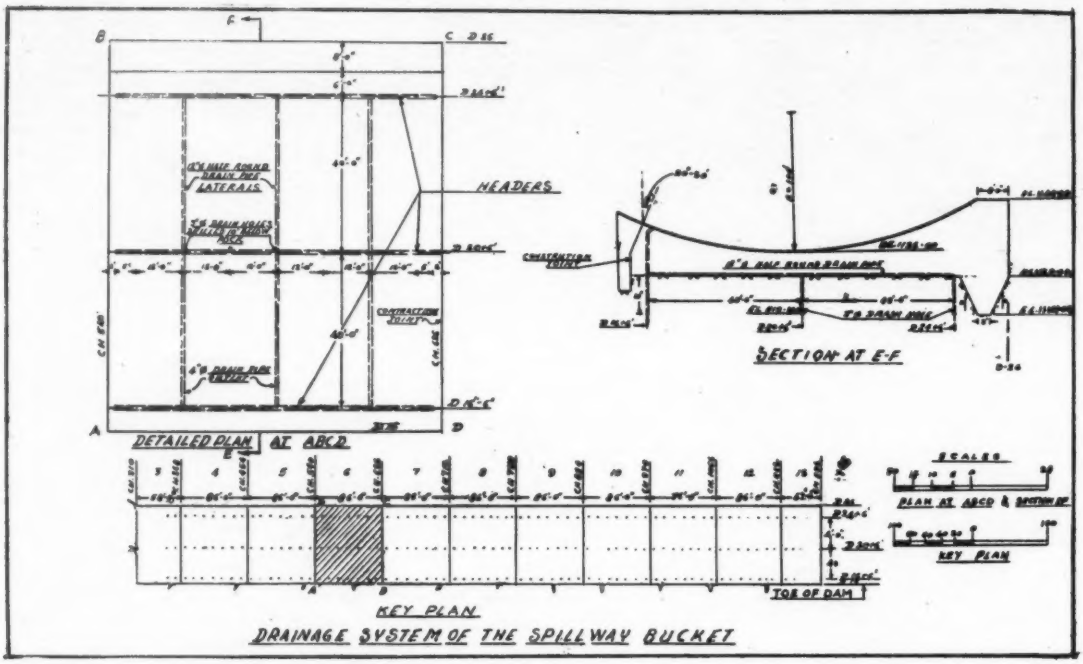


Fig. 2

(from foundation to E.L. 1160).

(iii)	From axis of dam to 100′ downstream face foundation E.L. 1225 to (From axis of dam to downstream face.)	Red cement mortar (Red cement: sand) 1:4 by volume.
(iv)	From El. 1225 to the top of dam in case of non-spill-way and upto the bottom of concrete in case of spillway.	Red cement mortar (Red cement: sand) 1:5 by volume.

Masonry of different kinds have been used according to the needs in the dam. The type, cross section shows the various kinds of masonry used.

At the beginning when the masonry is to be started on the prepared rock foundation great care is exercised. The foundation is tapped with light hammer and tested for soundness. The area is first of all moistened and given a thick neat cement slurry swabbing. Over this a thick layer of the red cement mortar of 1:2¾ proportion is spread. The stone which is examined and passed is placed on the mortar while it is still moist. The stone is then shaken well to permit its sinking into the mortar. Then it is hammered down by wooden malets of 10 to 12 lbs weight. The stones are set side by side as above, leaving a side joint of 1½″. Into these side joints mortar is filled up and cleaned stone chips are driven in by using hammers of 4 to 6 lbs. The stones are set on their natural beds in such a way that they do not shake. When the masonry is yet green the working crews are prevented from walking over them as they will disturb the set stone. The construction requires a very close supervision and is naturally a little slow as each course has to be raised not earlier than 24 hours after the lower course is laid. This constructed masonry is kept watered and cured and is never allowed to dry up.

CONCRETING

The Gandhi Sagar Dam contains 60 lakhs cft. of concrete. In the early stages the aggregate was hand broken and the concrete was mixed in concrete mixers near the places where they were to be laid. The construction machinery ordered for, when arrived, were suitably located at a central place. The aggregates required were then manufactured in the crushing plant which consists of (1) apron fed primary jaw crusher, (2) two gyrosphere secondary crushers, and (3) necessary conveyor belts and screens. The aggregates manufactured are conveyed by belts to different stock piles over a reclaiming tunnel. The concrete plant manufactures three grades of aggregates ¾″ to 3/16″, 1½″ to ¾″ and 3″ to 1½″.

Aggregates of several grades are used in the Gandhi Sagar Dam. Their mixes and strengths are as below:—

Class	Minimum 28 days 6″×12″ strength of neat cement concrete lbs./sq″.	Maxm. size of aggregate (inches)	Min. and Maxn. slumps (inches)	Location
A/1	2500	7	1 to 3	Concrete in spillway bucket except top 3′. Concrete in rifts and deep pockets etc.
A/2	2500	3	2 to 3	Fillet at the toe of the dam. Trash rack substructure base. Training walls except outer 3′.
A/3	2500	1½	3 to 5	Drainage and cross galleries and embedding fixed parts of outlet gates.
B/1	3000	3	1½ to 4	Upper 3′ of spillway bucket outer 3′ of training walls spillway piers. D/s face of spillway and power house substructure.
B/2	3000	1½	2 to 4	Power House walls floors over 12″ trash rack structure above base spillway bridge members—over openings elevator shaft-penstock pipes and draft tube portion.
B/3	3000	¾	2 to 4	Bridge slab-beams and parapets-blockouts around sluices-storage structure walls and floors less than 12″ and contraction joints.

The concrete for the dam is manufactured in the batching plant. The aggregates are lifted to the top of the batching plant by conveyor belts, and fed into four bins each meant for a particular grade of aggregate. Centrally to these are situated two bins, one for cement and the other for puzzolana (surkhi powder). The cement and surkhi powder are fed on to these bins by bucket elevators. The batching plant is provided with three one-eyed mixers. The materials for each mix is weighed through semi-automatic scales and discharged into mixers. The water is also automatically measured and added to the mixers. When all these three mixers are working the capacity of the plant is 60 cyd. per hour.

Below the batching plant is located a 2′ gauge loco track. The concrete buckets mounted on flat trolleys are drawn up below the discharging chute of the batching plant. The mixed concrete would be poured into the bucket by mechanically controlled gates and hauled by the locos to the loading platform under the cableways. To convey the concrete from the loading platform to several places in the dam, two cableways are provided. The cableways have a common head mast on one end while the other ends are attached to two independent tail cars moving on rails laid to a circular curve. One of the cableways is of 10 tons capacity while the other is of 5 tons. The cableways have a span of 2150′ and is controlled by an operator from the head mast end. Immediately the manufactured concrete arrives at the loading platform the buckets are lifted by the cableway and conveyed to the places of laying on the dam. At the

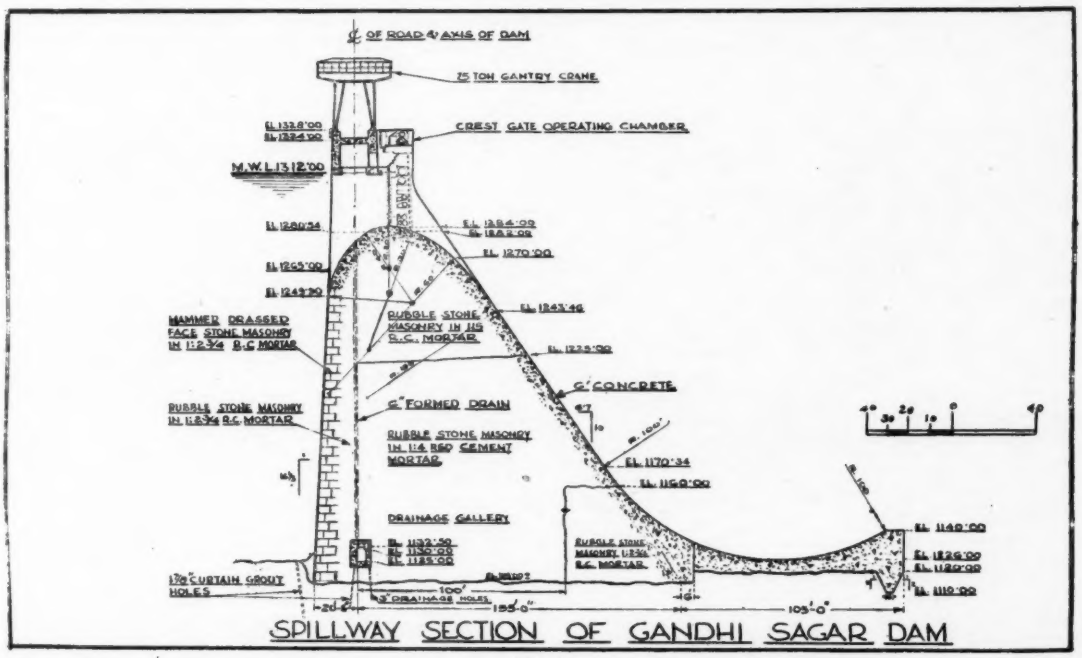


Fig. 3

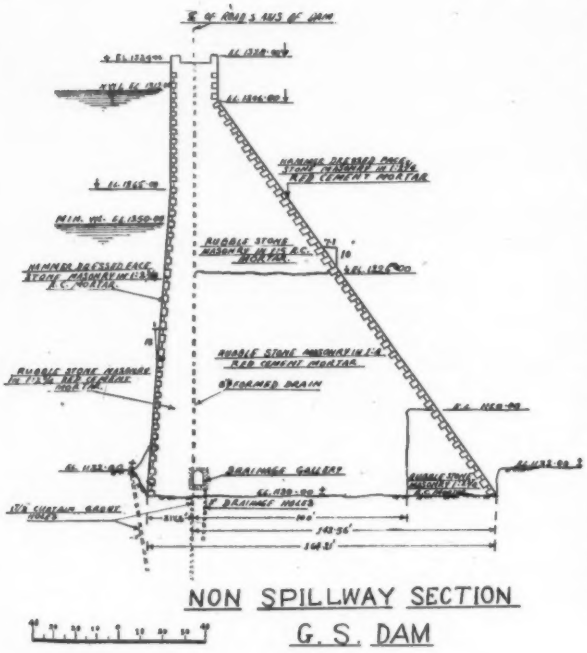


Fig. 4

laying places the buckets are lowered and emptied into position.

The concrete from the buckets is discharged into places at a little distance away from the form work. As the buckets are hung to the cableways the operators discharging the concrete from the bucket have to be very careful, as on account of the release of the load from the concrete bucket the track ropes of the cableway would swing up along with the bucket. As far as possible this action is counteracted by a suitable and timely lowering of the bucket by the operator at the control tower. The poured concrete is then vibrated by heavy duty vibrators or light duty vibrators depending on the place of the concrete placement. The concrete is normally laid in horizontal layers of 2½′ lifts. Where finished surface is inclined, the concrete will be normal to the inclined surface. The surfaces of the laid concrete after a period of 24 hours will be wire brushed and flooded with water jets under pressure to remove liatence and provide good rough surface for future layers.

In Gandhi Sagar Dam steel form works are provided as far as possible. These are of several sizes. These form works are strutted from the concrete side from collapsing or held back from falling away by tension wires. The steel shuttering is always given a coat of oil to facilitate easy striking of forms. The underside of slabs are to have a good appearance and uniform surface. To achieve these bulley staging is first built up. Corrugated iron sheets of 16 guage are spread over these. The corrugations are filled up with much, etc. upto 1″ above the ridges and consolidated by tampers and plastered over with lean cement mortar to required slopes. After the mortar is set, the surface is either given a smearing of oil or cow-dung wash. This form work gives a very fine surface to the slab and can be easily struck. For the spillway bucket, for the trash rack structures, for the transition of penstock, etc. special steel form works were provided.

The concrete in the Gandhi Sagar Dam is reinforced in all the places. Wherever the concrete is subjected to structural stresses, reinforcements are provided as per stress analysis. In all other places nominal reinforcements are provided near the surfaces of the concrete. For reinforcements only mild steel rounds bent to the required shapes have been used.

The surface of the concrete in the Gandhi Sagar Dam is rarely plastered over. The surface, immediately the form work is struck, is examined for honeycomb which is normally not present. In places, where they are the cement film is raked out and the honey-comb surface washed and splashed with rich cement mortar and rubbed with gunny bags.

POWER HOUSE

The power house is located on the downstream of the Gandhi Sagar Dam at its right extremity. The power house is 311′ long and 59′ wide, and is a reinforced concrete framed structure. It accommodates five machines each 23,000 k.W. with their centre lines 50′ apart. The power house at one end has, at elevation 1170, a service bay to facilitate overhaul or carrying out any repairs the machines may require. A small workshop is also attached to the same. The power house is provided with a 75 ton capacity travelling crane. The generator floor level elevation is 1144.00. The power house in length is divided into four blocks. Between the power house and the dam are located auxilary structures required for the running and control of the generators. These auxilary structures are in 3 tiers. The lowest at El. 1144 accommodates water pipes etc. The floor at El. 1160 is entirely meant for spreading cables, both power and control. In the floor at El. 1170 are provided the control room, reception room, shift engineer's room etc. These auxilary rooms at El. 1170 are air-conditioned.

Substructure of the machines

The turbines and generators are erected on heavy foundations. Lowest excavation for the substructure is about 45′ below El. 1144.00, the generator hall floor level. The water flowing from the reservoir through the penstock passes through the scroll case and finds its way out through the wicket gates of the turbines. This water flows out of the draft tube and draft channel to join the river again on the downstream side of

(Continued on page 36)

Launching of Precast Prestressed Pipe on Bridge of Kunu Syphon

By K. PRASAD

KUNU Syphon is one of the major cross drainage structures on Right Main Canal in Chambal Valley Development Scheme for passage of the canal water across river Kunu in Madhya Pradesh. This lies between Birpur and Sillipur railway stations on Central Railways (narrow gauge section). The structure is a syphon consisting of a 20′ diameter prestressed concrete pipe with 11″ as minimum thickness of shell and 5860′ in length between inlet and outlet ends. For a total length of 4925′ the pipe is laid on the ground over concrete footing on either banks of the river and the remaining portion of 935′ long is carried over a high level bridge across the river Kunu. This structure after completion, will be the longest prestressed concrete structure in Asia, with the unique feature of its design of prestressing on Freyssinet system both circumferentially and longitudinally.

The total length of 935′ of the pipe on bridge portion is being cast in eleven units each measuring 85′ in length, resting on Neoprene rubber bearings placed on the caps of the piers. Thus each unit of 85′ length is monolithically cast with the beams spans, each individual span—pier to pier—on the bridge and is simply supported. The deepest point in the river bed is about 80′ from the top of the pier. The total weight of each unit of the pipe is about 600 tons and it requires about 10,600 cft. of concrete to be laid. As per usual form of construction, it could be done by making platform for shuttering resting on staging made up from timber posts and ballies, etc. Since the river is in flood during the monsoon period and water flows with good velocity, the work could not have been carried on without interruption during this period. It was therefore, decided to cast it on specially prepared beds on ground and launch it on the piers with the help of steel gantries. Since the total weight of the pipe being quite enormous, it would have presented a problem of hauling if precast in one stage. The casting of the pipe is split up in two stages dividing it into two portions, viz.,

(i) Precast unit consisting of bottom beams supporting the lower quadrant of the pipe and interconnected with two end diaphragms and three cross beams. The weight of this unit being 360 tons.

(ii) The upper circular unit cast in situ weighing 240 tons.

Firstly, the unit is precast on the ground on the right bank of the river in a casting yard by putting all prestressing cables in position before laying the concrete. After the cables are partly stressed this precast unit is removed from the casting yard and placed on to the piers over Neoprene rubber bearings.

Then the shuttering for the cast in situ portion is prepared and concrete laid. Thus the 85′ length of the circular pipe of 20′ diameter with 11″ minimum thick shell resting on two main beams and three cross beams including the two end diaphragms is completed and launched in position on piers of the bridge across the river.

This paper deals with the details of operations adopted for launching the above precast unit of the pipe.

EQUIPMENT

There are two movable steel gantries consisting of trusses fabricated and assembled out of angles and channels of various sections, mounted on eight broad gauge wheel axles—the wheels resting on rails laid on the roadway lanes on either side of the bridge. From the top of each gantry are supported four hangers made from channel sections. These hangers are connected to two sling beams on either ends made up of channels section. On each gantry there are four hydraulic jacks of 50 tons capacity each with accessories resting on cross pieces fixed to the gantries and supporting the movable cross piece which moves up and down when lifting and lowering the precast unit. Two winches connected with pulleys are mounted one on each side of the gantry in the front to effect forward movement of the gantries. In order to lift hangers and sling beams when not in operation there are two winches placed on the top of each gantry. There is also an anchoring arrangement in front of the gantries which is ahead by about 100′ and can be shifted when required till the span where precast unit is to be placed is reached. The total weight of the gantry with all equipment is nearly 40 tons.

OPERATIONS OF LAUNCHING

The entire launching operation can be sub-divided as below:

(i) Lifting of the precast unit from its base in the casting yard.

(ii) Dragging it over to the piers.

LEFT TO RIGHT: *Hydraulic jack with pin inserted in hangers and resting on fixed beam and supporting movable beam at the top, jack accessories on top platform of the gantry, and bottom of gantry on the wheels an the front winch.*

(iii) Lowering it in position on to the piers on Neoprene bearings.

For lifting the precast unit from its base after about four days of laying the last pour of concrete and stressing the cables partly, the four sling beams are inserted below the precast unit through the notches left below the casting beds. These slings are again connected to the eight hangers through 3″ diameter M.S. pins. The cross beams fixed to the top truss of the gantry supports these hangers on another pin of 3″ diameter.

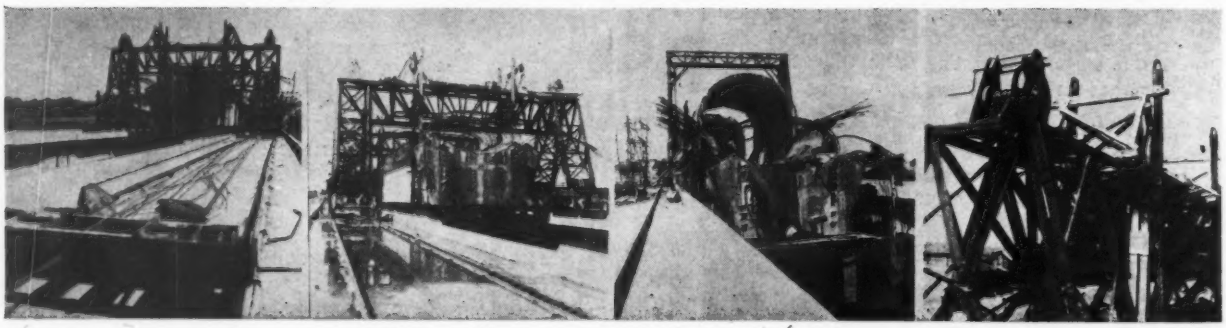
After fixing the sling beams and hangers in position, the 3″ diameter is inserted in the hole made at 5″ centre to centre in the hanger through the holes made in the movable beams.

The four numbers of hydraulic jacks mounted on the gantry are operated to raise the precast unit by about 5½″. Due to this upward movement of the hydraulic jacks the pin resting on the fixed beams is also lifted with the hangers and is subsequently taken out and inserted in the next hole adjacent to it which is at a distance of 5″ from the previous hole. After this the jacks are released, leaving the precast unit lifted by 5″. At this stage the precast unit is resting on the slings the load being borne on the 3″ diameter pins passing through the holes of rangers and resting on the fixed beams.

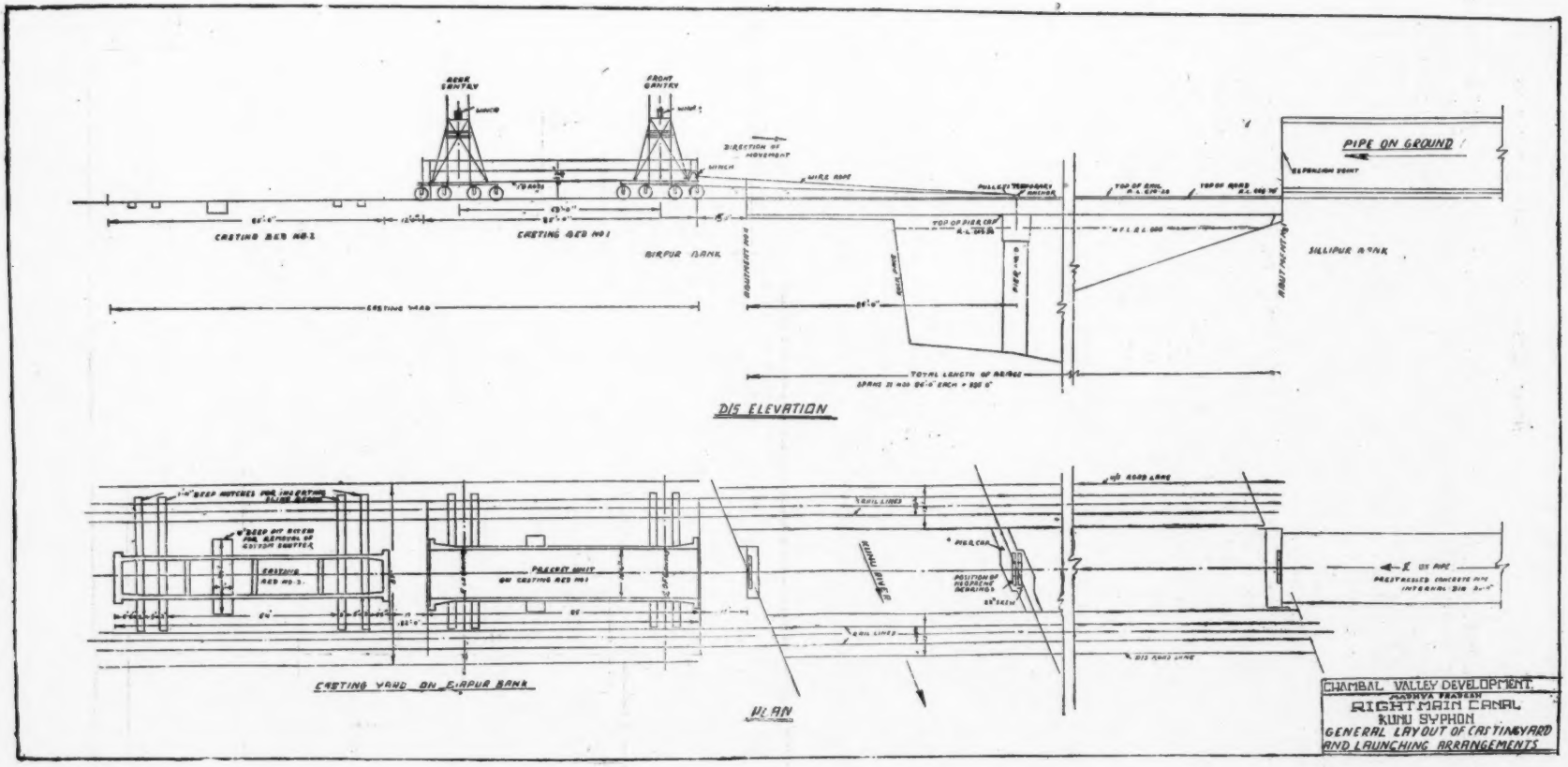
The process is repeated at the other gantry and the other end of the unit is lifted by 10″ and thus the difference of level at two ends of the unit is not more than 5″ at any time. But when the unit is lifted in the last stage, the difference of 5″ is made up and the unit is now lying horizontal, ready for being launched. The unit is lifted by about 25″ in all in order to have a clearance at the bottom to move the unit horizontally without any obstruction and this is done in stage of 5″. This operation of lifting the unit by 25″ takes about 8 to 10 hours in all with the help of 8 to 10 khalasis and an experienced supervisor.

Moving the unit

After the unit is lifted to the required height, the winches mounted on the front gantry are operated. The temporary anchor fixed at about 100′ ahead of



LEFT TO RIGHT: *Gantry connected to anchor during operation; precast unit under horizontal movement; top truss of gantry with winch on the top platform; precast unit launched into position on pier caps.*


REAR GANTRY
FRONT GANTRY
DIRECTION OF MOVEMENT
WINCH
WIRE ROPE
PIPE ON GROUND
CASTING BED NO 2
CASTING BED NO 1
BIRPUR BANK
SILLIPUR BANK
CASTING YARD
TOTAL LENGTH OF BRIDGE
DIS ELEVATION
CASTING YARD ON BIRPUR BANK
PLAN
CHAMBAL VALLEY DEVELOPMENT
MADHYA PRADESH
RIGHT MAIN CANAL
KUNU SYPHON
GENERAL LAY OUT OF CASTING YARD AND LAUNCHING ARRANGEMENTS

the gantry has got two pulleys fixed to it and on which the ropes from the winches pass. The other end of the rope is tied to the gantry on a pulley fixed to it. The winch is operated manually by khalasis and as it works, the rope goes on winding, causing the gantry to move towards the anchor.

The rear gantry is fixed to the front one through four 1″ diameter M.S. rods and with the movement it rolls on the wheels resting on broad gauge rails laid on either side of the bridge. When the gantries reach near the anchor, the anchor is shifted forward by another 100′. The unit moves horizontally at a speed of 30′ per hour and requires 8 coolies to operate it.

Lowering the unit :

The unit having been moved on to the span over the piers, it is required to be lowered by about 105″ in all in order to rest it on the Neoprene bearings over the pier caps. The process of lowering is just the reversal of that of lifting. The hydraulic jacks are operated and pistons are raised to about 6″ and the pins are inserted in the hanger hole through the holes in the movable cross beams. At this stage the unit is resting on the jacks through the movable cross beams. The other pin is inserted in the hole 5″ above fixed cross beam. The hydraulic jacks are then released and the unit comes down by 5″ and rests on the fixed cross beams through the 3″ diameter pins. This process is repeated on the other gantry and that end is lowered by 10″. Then the first end which is already lowered by 5″ is again lowered by 10″ thus maintaining a difference in level of either ends not more than 5″ at a time.

After the unit is lowered by 105″ it is allowed to rest finally on the Neoprene rubber bearings. Slight adjustments for bringing the unit in correct alignment with the other units are effected with the help of Freyssinet flat jacks which can be inserted in the grooves left in the bottom of the precast unit without damaging the concrete due to unequal pressure which might result if the adjustments are made otherwise. The gantries are then rolled back to the casting yard by releasing the sling beams and lifting them with the help of the two winches mounted on the top of the gantry.

ECONOMICS OF THE OPERATIONS

The total cost of the gantries consisting of trusses fabricated and assembled out of angles and channels of various sections including wheels, winches and hydraulic jacks, etc. works out to about Rs. 1,05,000. Taking depreciated value of the same at about

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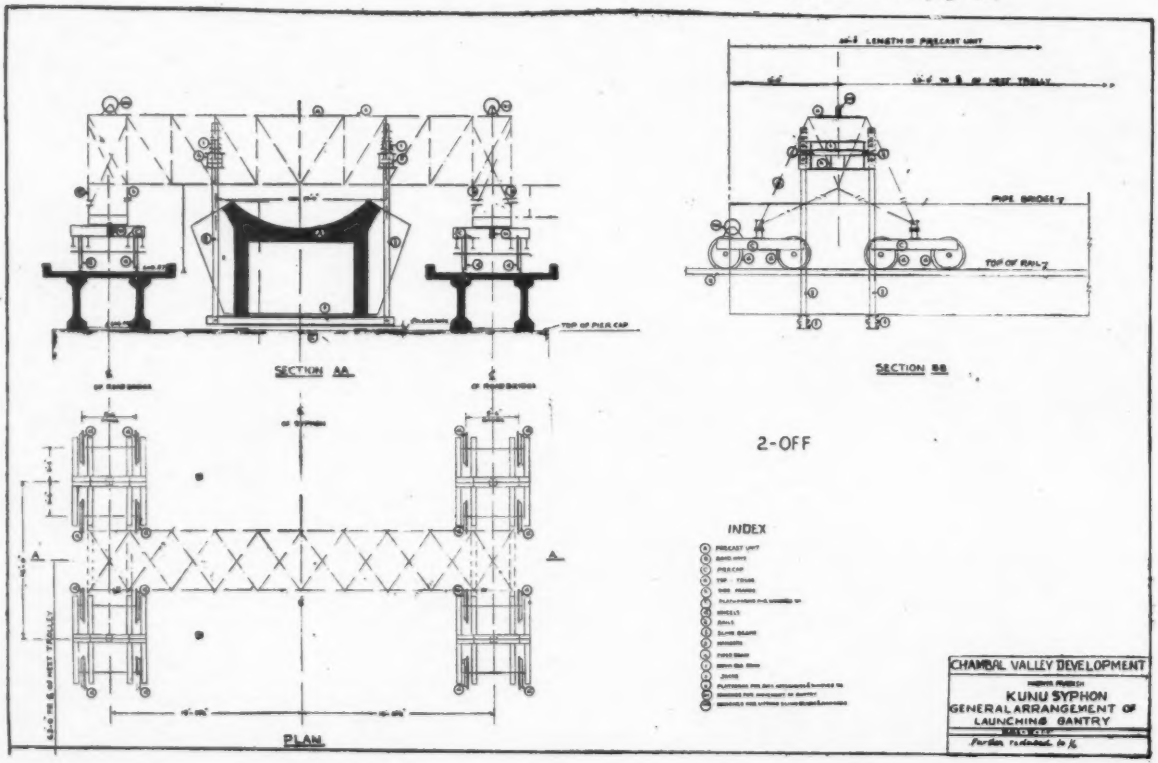


Civil Engineering Works of The Gandhi Sagar Power House

By B. S. BHAWANISHANKAR

THIS article deals briefly with the water conductor system in the Power Dam and the constructional features of the Power House and Switchyard.

The works connected with the water conductor system are:

1. Trash rack structure at the entry of the penstock openings.
2. Arrangements connected with the provision of a stop log gate.
3. Bellmouth entry into the rectangular penstock gate openings.
4. The gate chamber.
5. The transition from the rectangular section to the circular section of the steel penstock.
6. The steel penstock.
7. The reducer section at the entrance to the scroll casing.
8. The draft tube shaft and the draft tube openings with transitions.
9. The tail race channel.

The Gandhi Sagar Power House is located at the toe of the Gandhi Sagar Dam. The width of the river at the dam site between the steep banks is 1200′. Of this about 850′ length is utilised by the spillway section and the guide walls leaving only about 350′ for the location of the power house. The power house proper is 311′ long and with the provision of a workshop annexe. The power house extends practically to the full length from the spillway to the vertical bluff of the river.

The draft tube channel down the power house is 212′ wide. After providing for this the width available was inadequate for the location of the switchyard. It was therefore necessary to cut into the bank of the river by about 50′ and use the spoil to fill up the gap between switchyard retaining wall and the hill to keep the switchyard platform above F.R.L. of the Rana Pratap Sagar which when full would back up 40′ against the power house at site.

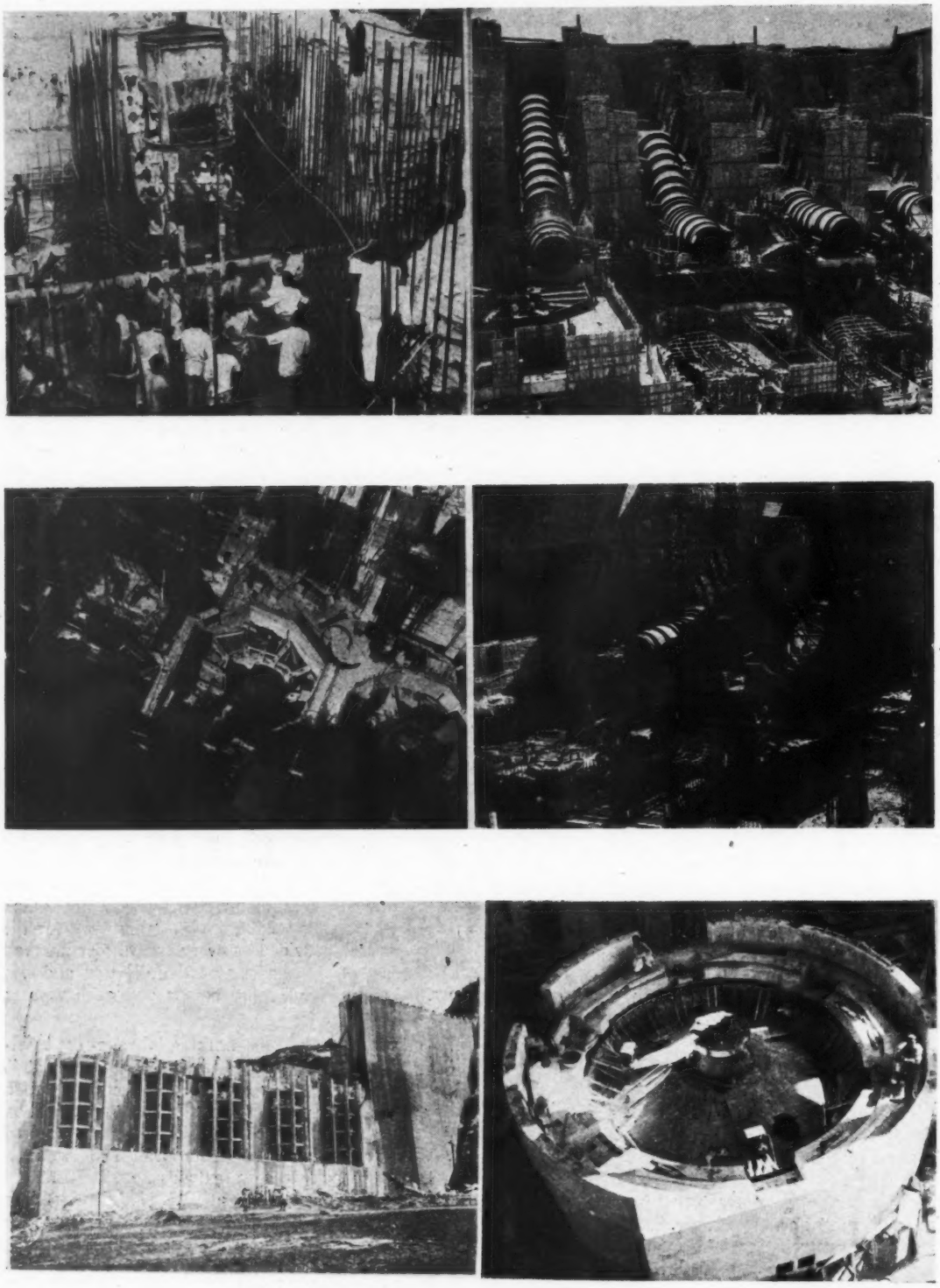
POWER DAM

The power dam is that portion of the dam immediately upstream of the power house and is constructed in stone masonry similar to the other sections of the dam except for concrete lining around galleries, penstock gate chambers, penstock pipes etc., where reinforced cement concrete is provided for obvious reasons. Five penstock pipes of diameter 15′-6″ have been built into the body of the dam and have their centre line levels at the inlet at R.L. 1205.5. For smooth flow of water into the penstocks, each penstock has been provided with a bellmouth for the rectangular openings which are transitioned to a circular shape in a length of 24′-3″ to fit the steel liners. The steel liners have an angular inclination of 30° to the horizantal in the body of the dam, and then take off horizantally to connect the reducer sections whose diameter varies from 15′-6″ to 12′-4″ in a length of 12.1′ having its centre line level at E.L. 1134.00 which is also the centre line level of the turbine machinery. The reducer section is connected on to the spiral casing or the scroll case housed in the power house building. The water after passing through the scroll case wicket gates and turbine, flows out through the draft tube openings which are transitioned for smooth exit from the power house.

At the upsteam of the dam the penstocks have been provided with trash rack structures and grills in the front to prevent the entry of trash into the turbine machinery. The trash rack structure has been supported on solid masonry foundation right from the bed of the river as this type of support was found to be speedy and more safe.

The full construction of the R.C.C. trash rack structure was done with rigid steel form work for the columns cast in situ and the stiffner beams were precast and fixed at site while casting the columns. This method was found to be very easy and quick dispensing away the elaborate centering work for the stiffner beams provided at every twelve feet interval. The weight of each beam was about 3½ tons and was positioned by simple pipe booms and cableways as was convenient.

A detailed study of the working tables of the reservoir revealed the water level would go below R.L.1300 (once in every three or four years) as such the trash rack structure has to be taken up above this elevation to facilitate maintenance of grills whenever required without depleting the reservoir level. The top level of the trash rack structure extends upto R.L.1301.75 with its bottom located at R.L.1179.75. Between R.L.1179.75 and R.L.1227.75 are the grills 20 for each penstock, forming the screen to the flow entering into the penstock. From the top of the slab at R.L. 1228.75 upto 1301.75 an R.C.C. enclosure 1′-3″ thick prevents the entry of the debris into the penstocks.



Illustrations showing construction in progress.

through the stop log gate chamber. From 1300.75 to 1301.75, a R.C.C. slab is provided over the trash rack columns to facilitate the maintenance of the trash rack grills. A hatch cover is provided at R.L. 1301.75 in the stop log groove chamber between the enclosure wall and the vertical face of the dam. This arrangement suffices the provision of the grills upto only RL.1227.75 thereby saving a lot of steel.

PENSTOCK GATE

Each penstock has a regulating gate of size 12.18′ × 18.5′ which moves on rollers fitted between guided tracks embedded in the vertical shaft opening right up to the top of the dam. The gates when closed rest on sills at R.L.1189.56.

OPERATING GALLERY AND THE MACHINERY

The housing for the operating machinery is located at R.L.1312 in an operating gallery 12′ below the top of the dam and running parallel to it. The gallery is 5′ × 7½′ with enlarged sections where the shaft of the penstock gate meets. The top of the shaft at R.L. 1324 is provided with removable precast concrete covers so that the gate and the machinery can be hauled up for replacements or for repairs. The lifting device consists of a servomotor pump, hydraulically operated for smooth motion of the gate. The traverse of the gate is indicated on a dial showing the position of the gate during the travel. The gate up and the gate in position is also automatically indicated in the power house through electrical communication.

STOP LOG GATE

Between the regulating gate shaft and the trash rack structure is another shaft formed by the R.C.C. enclosure wall and the vertical face of the dam. The shaft provides for the lowering of the stop log gate of size 16′-2″ × 26′-8″ to close the penstocks in case of an emergency when the penstock gate cannot be operated, and for maintenance. The stop log gate, manufactured locally, is of the sliding type moving on steel guides and will be operated by the same travelling crane moving over the parapets of the dam and meant for operation of emergency gates. One common stop log gate is provided for all the five penstocks.

BY-PASS VALVE GALLERY

The penstock gates operate under balanced pressure condition. The achieve this by-pass valves with pipes connecting the reservoir upstream and the penstock downstream of the gate are provided in a gallery at R.L. 1214.5. This is approachable from the drainage gallery, elevator shaft or from the top of the power house through an adit.

ELEVATOR SHAFT

The power station is also approachable by an electric freight lift operating in a suitable elevator shaft.

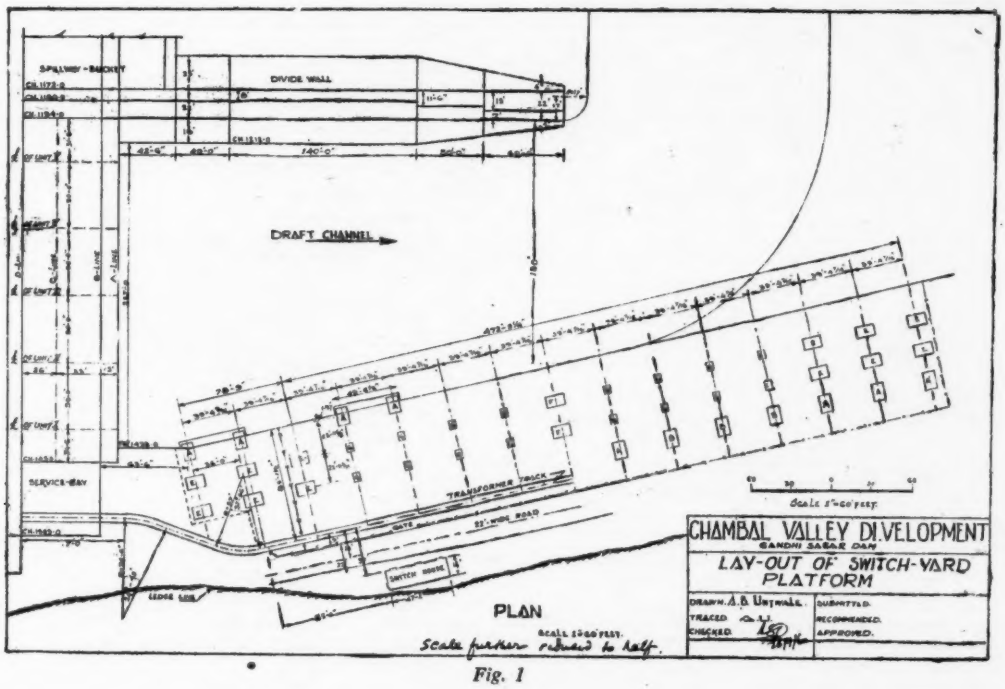


Fig. 1

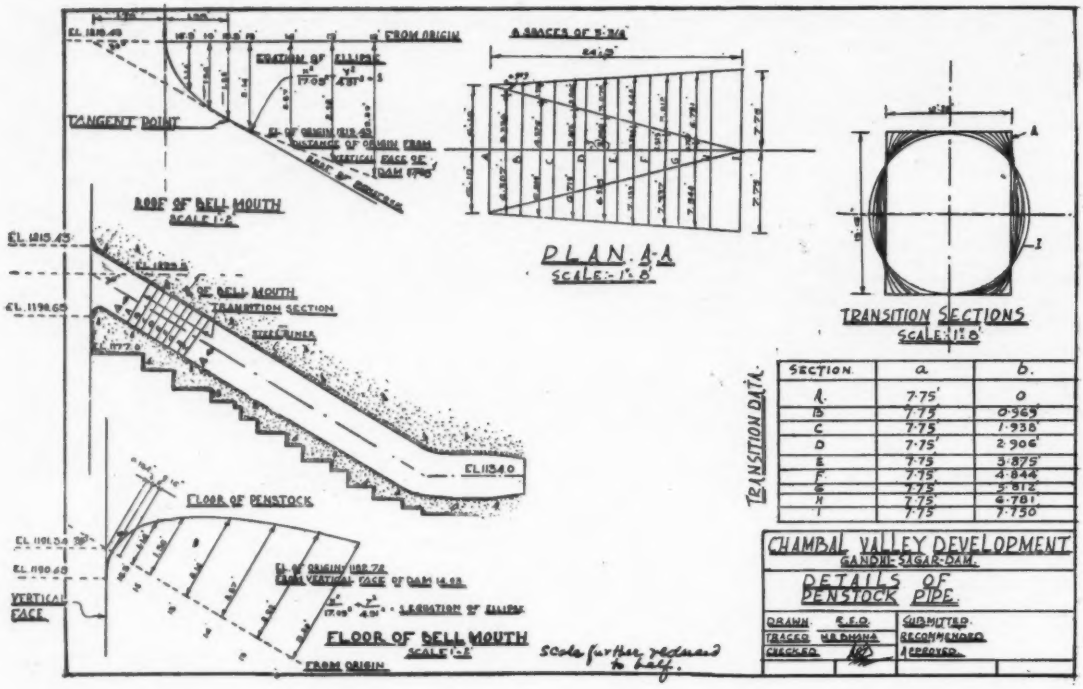

PLAN A-A
SCALE:- 1" = 8'
TRANSITION SECTIONS
SCALE:- 1" = 8'
ROOF OF BELL MOUTH
SCALE 1"=2'
FLOOR OF BELL MOUTH
SCALE 1"=2'
FLOOR OF PENSTOCK
TRANSITION DATA
SECTION | a | b
A | 7·75' | 0
B | 7·75' | 0·965'
C | 7·75' | 1·930'
D | 7·75' | 2·906'
E | 7·75' | 3·875'
F | 7·75' | 4·844'
G | 7·75' | 5·812'
H | 7·75' | 6·781'
I | 7·75' | 7·750'
CHAMBAL VALLEY DEVELOPMENT
GANDHI SAGAR DAM.
DETAILS OF PENSTOCK PIPE.
DRAWN: E.F.O.
TRACED: M.R.DHAWA
CHECKED:
SUBMITTED:
RECOMMENDED:
APPROVED:

Fig. 2

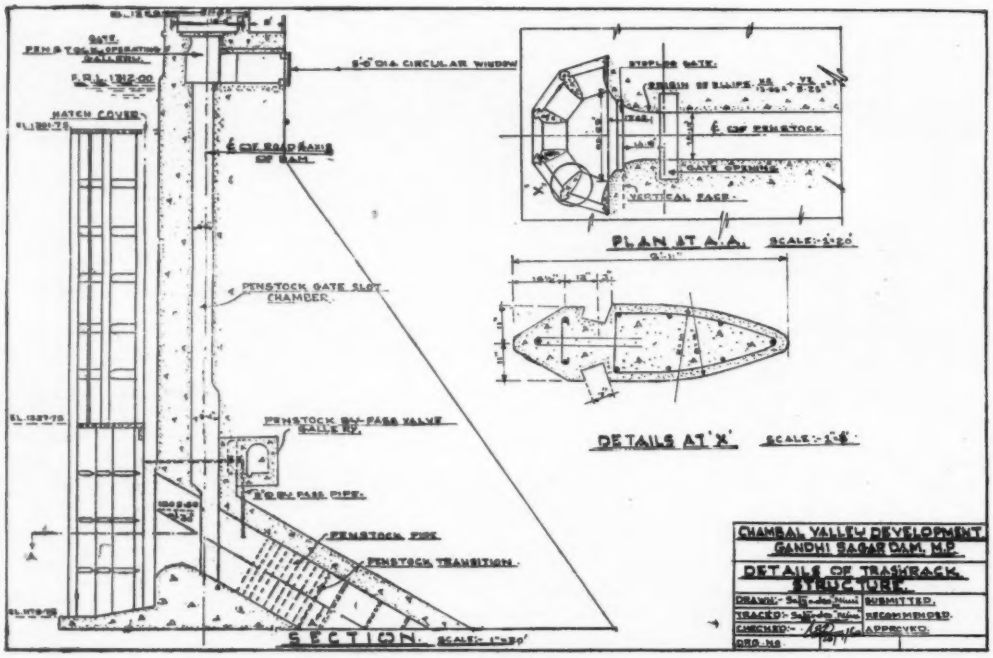

PLAN AT A.A.
SCALE:- 1"=2'
DETAILS AT 'X'
SCALE:- 1"=1'
SECTION.
SCALE:- 1"=20'
PENSTOCK GATE SLOT CHAMBER
PENSTOCK BY-PASS VALVE
PENSTOCK PIPE
PENSTOCK TRANSITION
CHAMBAL VALLEY DEVELOPMENT
GANDHI SAGAR DAM. M.P.
DETAILS OF TRASHRACK STRUCTURE.
SUBMITTED.
RECOMMENDED.
APPROVED.

Fig. 3

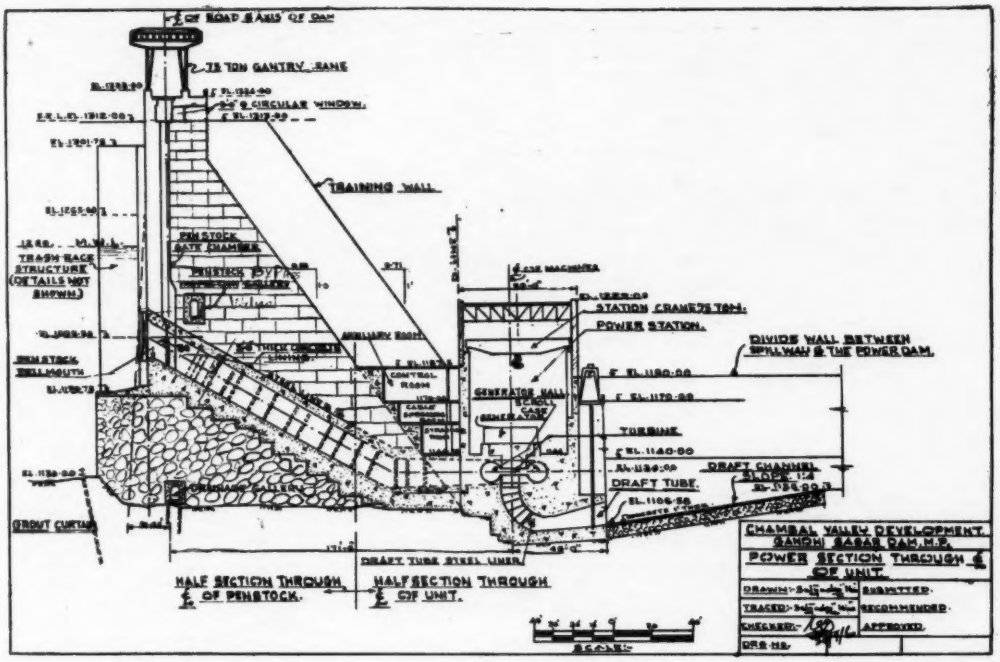


Fig. 4

THE POWER HOUSE

The general dimensions of the building are 311′ long and 59′ wide. The greater dimension accommodates the housing of the five power units fed by the five penstocks from the dam. The structure is mainly of reinforced cement concrete. The main part of the building is the generator hall. It is made up of 32 heavily reinforced columns 16 in a line in the upstream and 16 in the downstream of the units. The minimum cross section of a column upto crane beam level is $4\frac{1}{2}' \times 2\frac{1}{2}'$. The foundations of the columns have been taken right down to the rock level at R.L. varying between R.L.1105 in downstream to 1120 in the upstream. These columns braced with the crane beam of 4′ depth and the truss beam of 2′ form a framed structure. There are three transverse contraction joints in the generator hall and at these joints double columns have been provided for freedom of movement due to temperature, shrinkage etc. Between these joints the structure forms an independent frame by itself.

The construction programme of the building was phased in convenient stages. This phasing of particular portions at a definite stage helped the erection work of the machines and its accessories. The civil and the electrical works are interlinked in a construction work of this type and a close development of both had to be done in a harmonious way.

EXCAVATION OF THE FOUNDATIONS FOR THE MACHINES

The detailed drawings of the excavations in stages

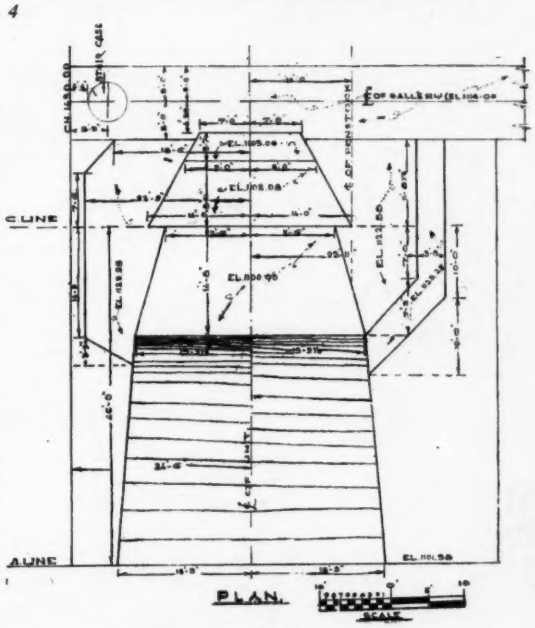


Fig. 5

were worked out so that excavation to the required levels was done. The final level for excavation was so fixed up as to provide minimum depth of 5′ concrete over the hard rock.

The excavation for the foundation for all the units were taken up simultaneously before commencement of concrete in the first unit and completed. The foun-

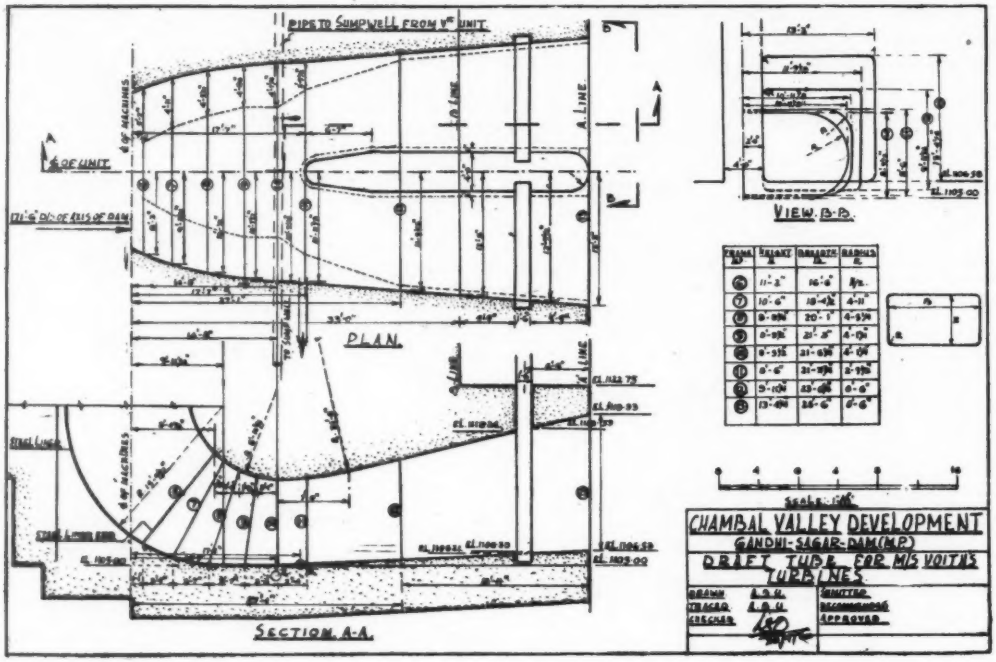

PIPE TO SUMPWELL FROM 1st UNIT
PLAN
SECTION A-A.
VIEW B-B.
CHAMBAL VALLEY DEVELOPMENT
GANDHI-SAGAR-DAM(M.P.)
DRAFT THDR. FOR M/S VOITH'S
TURBINES

Fig. 6

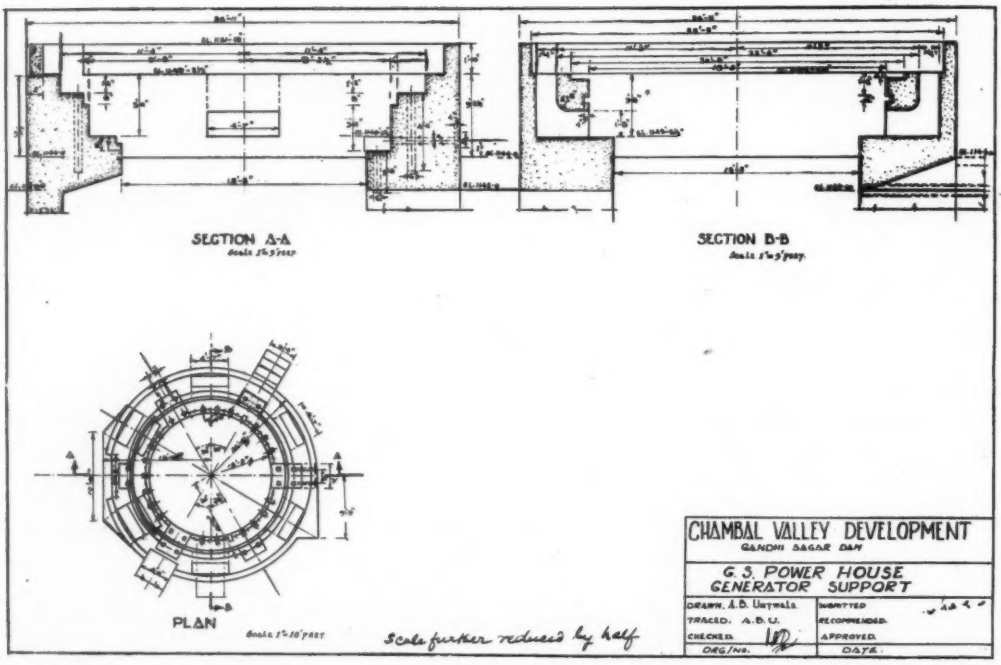

SECTION A-A
SECTION B-B
PLAN
Scale further reduced by half
CHAMBAL VALLEY DEVELOPMENT
GANDHI SAGAR DAM
G.S. POWER HOUSE
GENERATOR SUPPORT

Fig. 7

dation was consolidation grouted. The foundations and the concreting of the draft tube were done in pours not exceeding 5′ in depth. Timber form work was used for the transitions of the draft tube. 3″ diameter 12′ to 15′ deep drainage holes at suitable intervals of 5′ to 10′ have been provided in the floor of the draft tube to release uplift pressures.

DRAFT TUBES

Out of the 5 units, 3 units have similar sections for draft tube corresponding to the elbow type of M/s. Voith, who have supplied the turbines for the first three units. The fourth unit is of different shape and design, as the turbine and generator for this unit are supplied by M/s. Hitachi Ltd. For the fifth unit the excavated pit is left over untouched to facilitate construction in keeping with the requirements of the suppliers of the machines. Only the draft tube exit is constructed similar to the other four.

CONCRETING OPERATION

The concreting of the machine foundation was taken up in stages. In the first stage, the concreting of the draft tube and upto 4′ below the machine hall level, with a block out to seat the scroll case, was done. Suitable pedestals at intervals in the block out were left to facilitate the insertion of mechanical jacks to align the scroll case liner in true position. When the scroll case was truly aligned after fabrication, second stage of concreting around the scroll case was taken. This had to be done very carefully so as not to leave any air pockets which are undesirable. The scroll case was heavily asphalted all around to minimise transference of undue stresses to the concrete during the heaving up of scroll case liner when filled under pressure.

Along with this work the raising of the main columns and beams and the station walls was taken up. In the final stage the concreting of the generator support was taken up. Timber form work with plain G.I. sheet lining was used for the circular generator supports. The generator supports had a number of block outs and heavy reinforcement. Major concreting was done by the cableway in the foundations and for small items concrete was mixed locally by mixers.

MAIN COLUMNS AND BEAMS

Concreting of the main columns and beams was done mostly by mixing the concrete by volume batching at site. A mix proportion of 1 : 1½ : 3 was used. ¾″ thick plywood was used for the formed surfaces of the columns and beams which gave excellent results. These forms could be used as many as twelve times without any deterioration. Priority was given to complete the columns, the crane beams and truss beams, unit by unit, to facilitate the erection of the 75 ton travelling crane used for the speedy erection of the machinery as and when the civil engineering works of the machine foundation got ready. Similarly the

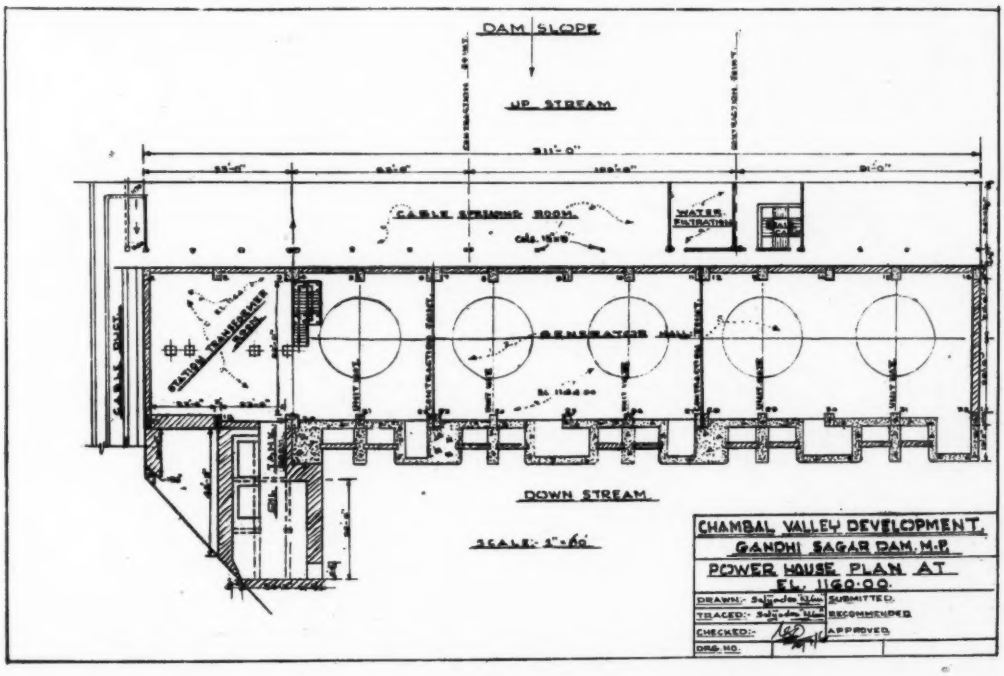


Fig. 8

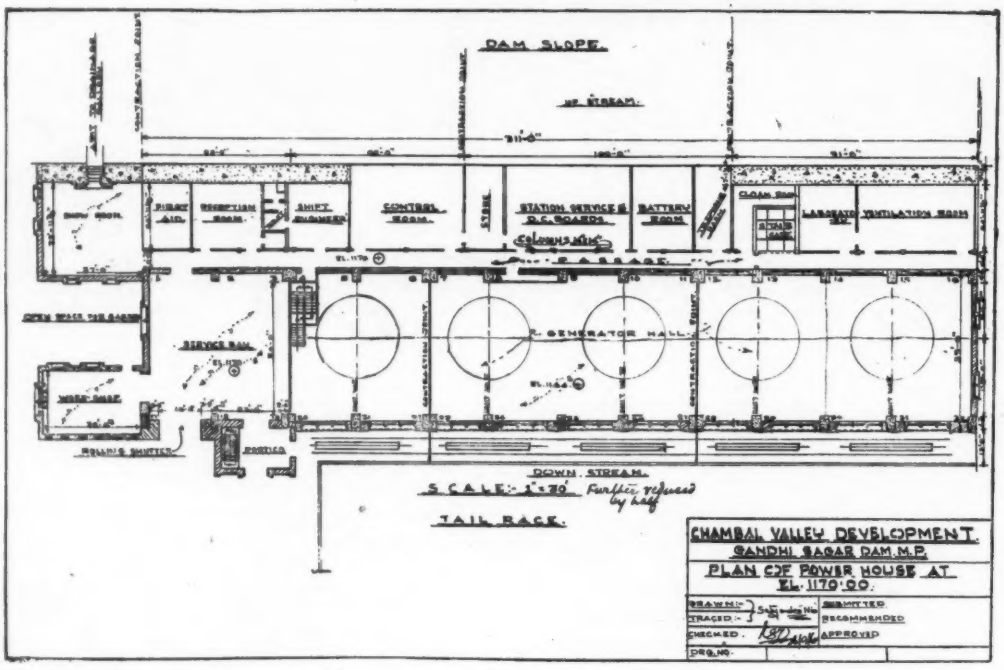
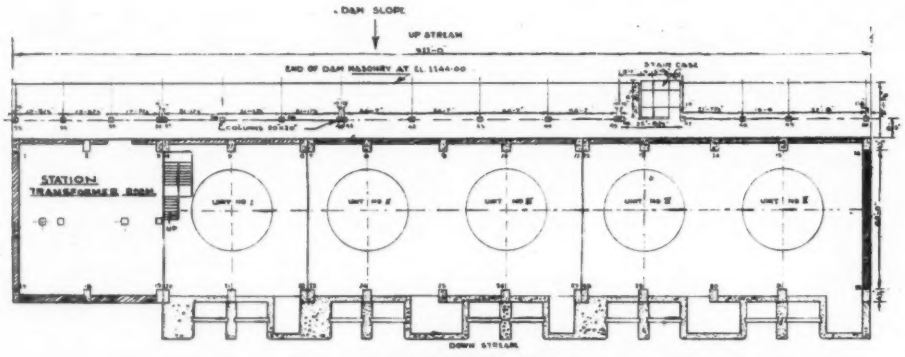


Fig. 9



PLAN AT EL 1144·00
Scale 1" : 60'

Fig. 10

early completion of the truss beams enabled the erection of roof trusses and the roofing over the power house. This helped the erection of machines during the monsoons and inclement weather.

GENERATOR HALL ROOFING

28 steel trusses of the N girder type have been used to cover the 311′ length of the generator hall and the service bay. The height of the truss at the middle is 9′ 10″ and at ends 7′ 10″. Each girder has been provided with plate bearings, one end fixed and and the other end free. Double trusses have been provided at contraction joints. Steel channel purlins at an interval of 3′ centre to centre, span the trusses over which 16 gauge corrugated G. I. sheets have been mounted. The top of the sheets have been finished up with 3½″ reinforced cement concrete separated by a mortar pad to cover up the corrugations of the sheet. The surface of mortar pad was smoothened and lubricated with oil to ensure freedom of movement to the R.C.C. slab resting above due to the shrinkage and temperature stresses. The R.C.C. slabs were poured in sizes of approximate 55′ × 30′ at a stretch and are connected to the adjacent ones by crimped copper strips forming the contraction joints. To ensure absolute water tightness it

is further finished on top with two layers of asphalted tar felt. A ceiling of A. C. sheets has been provided at the bottom of the trusses. This method of roofing construction was found to be economical and quick in execution.

SERVICE BAY

Next in importance to the generator hall is the service bay adjoining to it but at a higher level. The generator hall floor level is at R.L. 1144 whereas the service bay floor is at R.L. 1170. As one approaches the power station, the first thing one encounters is the service bay which is at the same level as the approach road. Heavy loads can directly be taken right below the 75 tons gantry crane. The floor slab is 1′ thick, spanning on 4′ to 5′ deep beams supported by sturdy columns from below. The slab has been designed for 1000 lbs/sq. ft. This slab was completed before the machine foundation so that the heavy turbine and the generator parts like the runner, the shaft, the rotor and the stator could be unloaded on to the service bay from where they were lifted directly by the gantry crane to be lowered into their permanent position for the assembly of the turbine and the generator machinery.

STATION TRANSFORMER ROOM

Directly below the service bay is located the station transformer room where the transformers and 11 kV switchgear are installed for the local distribution of power: for the dam, the G. S. Colony, Bhanpura, Rampura and Jhalawar Patan. An oil tank room is also built adjacent to this room to feed the oil for the transformer. In the oil tanker room a blower is also located to draw the air over the tail race channel into the transformer room to cool the transformers.

THE AUXILIARY ROOM

These are located just behind the generator hall of the main building, almost hugging the rear slope of the power dam. The main building and these rooms are separated by a longitudinal expansion joint all along and connected by a copper strip. The rooms are built in three tiers. One with floor level at R.L. 1144 and another at R.L. 1160 and the topmost floor at R.L. 1170. The auxiliary rooms actually form the nerve centre points for the control and running of the power station, of which the rooms located at R.L. 1170 is the most important and in which the control room of the power house is situated. The floor at R.L. 1160 is for cable spreading wherein the power and the control cables are collected and arranged in trays, leading into power cable and control cable tunnels below the switchyard for feeding to the transformers.

At R.L. 1144 are the cooling water mains and pipe connections tapping out water from the penstocks for circulation around the generators for cooling purposes.

The entire structure of Auxiliary rooms is made up of R. C. C. frames brought right from R.L. 1144

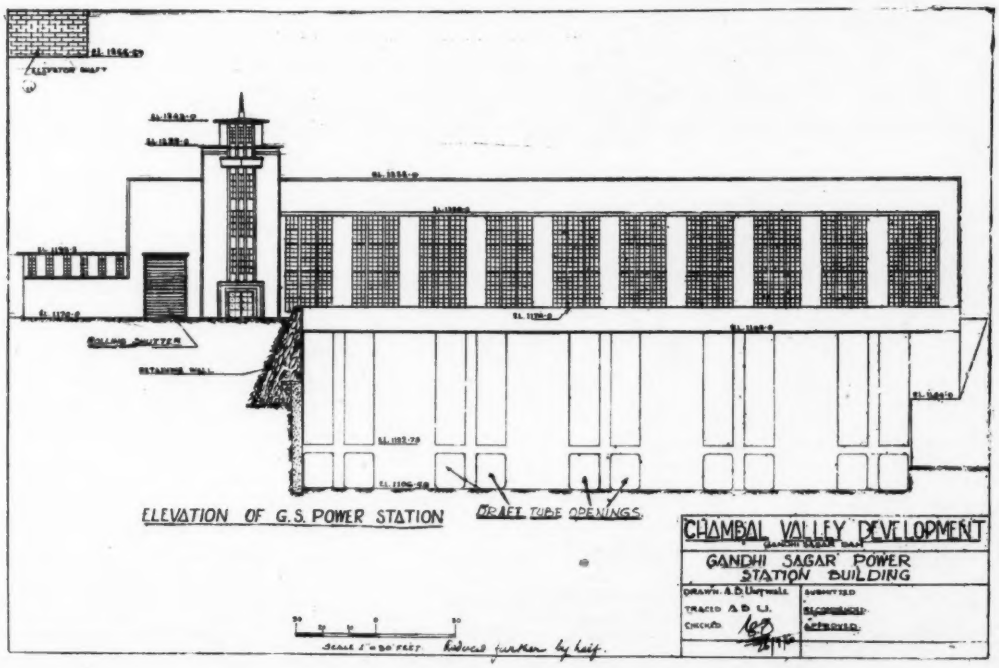


Fig. 11

to R.L. 1187.5 the top roof slab of the rooms. These frames between contraction joint have a system of cross girders bracing into the rear profile of the dam and between the cross girders the slabs at different floor levels, have been constructed as continuous slabs. Plywood form work was used for all the columns and girders and beams. The slabs had plastered form work on C. G. I. sheets supported on a centering of ballies. The top roofing slabs have been provided with a two layer asphalted tarfelt for water tightness of the rooms.

FILLER WALLS AND PARTITION WALLS

As mentioned earlier, the power house building including the auxiliary rooms were built as a framed structure first, without walls, excepting the down-stream station wall up to R.L.1170. Later on, the filler walls between the columns and the partitions to make distinct rooms were built. These walls have all been built in brick masonry reinforced with 8 gauge wires. The partition walls have been built in 9″ thickness and the others are thicker depending on the requirements. All the walls in the auxiliary rooms have been plastered with a base coat of grey cement mortar and a finishing coat of white cement (silvicrete). The plaster has been reinforced with chicken mesh to prevent hair cracks due to shrinkage. The main hall is provided with plaster of grey cement and finished with snowcem paint on the surface.

FLOORING

The auxiliary rooms at R.L.1144 and R.L.1160 have been finished with granalitic flooring as they are normally subjected to heavy duties. The auxiliary rooms comprising the control room station, D.C. board room, the shift engineer's room at R.L.1170 and the generator hall including the transformer room have been provided with marble mosaic tile finishing. The turbine walls exposed above the generator floor level are finished with marble mosaic in situ. A low skirting is provided in all the auxiliary rooms at R.L.1170 and a *Dado* in the generator hall.

WINDOWS AND DOORS

Steel windows and doors on the external wall have been provided and wire cast glazing has been provided for panes on the outer walls. The auxiliary rooms have been provided with block board flush doors as the rooms at 1170 are all air-conditioned.

EXTERNAL RENDERING

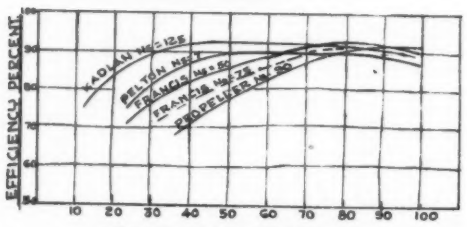
The exterior of the building is finished in cement mortar plaster and coated with snowcem paint of pleasing colours .The face of the architectural columns in the front elevation have been finished with dark marble mosaic in situ. Special precast concrete blocks in white cement have been extensively used for architectural effect in the front elevation of the building.

PERIOD OF EXECUTION

The work on the power house building was started in October 1957 and scheduled to be completed by November, 1960. During the years 1958 and 59 in order to continue constructions throughout the year, even in the monsoon, coffer dams in the form of horizontal arches in the upstream in front of the block-outs in the masonry for penstock opening and a cellular coffer dam in the tail race channel to prevent the water entering during the floods had been built. The horizontal arches in the front were dismantled in May 1959 when the power dam with penstock gates came up above the flood level and the cellular coffer dam in the tail race channel, between the divide wall of the spillway and the retaining wall of the switch-yard was dismantled by June 1960 when the down-stream wall of the power house had been completed. The construction of two coffer dams enabled work in power house area during floods and rains of the monsoon months and avoided costly dewatering at

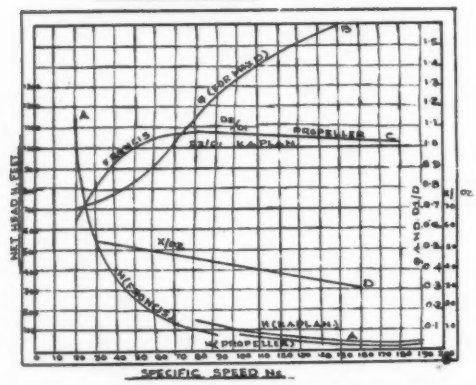
(Contd. on page 35)

APPENDIX I



LOAD EFFICIENCY CURVES FOR DIFFERENT TYPES OF TURBINE.

APPENDIX II



D1 MAXIMUM RUNNER INLET DIAMETER, IN D2=MAXIMUM RUNNER DISCHARGE DIAMETER IN. X= DISTANCE BETWEEN MECHINE CENTER LINES IN N= SPEED R.P.M Q= PERIPHERAL COEFFICIENT. HAMET HEAD ET P= B.H.P. OUTPUT.

Fig. 12 & 13

RAGHAVA CONSTRUCTION COMPANY

CONTRACTORS

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Works completed by us in the year 1960.

Works executed at

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(West Bengal)

GANDHI SAGAR DAM
(Madhya Bharat)

NAGARJUNA SAGAR DAM
(Andhra Pradesh)

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QUARRIED 30 LAKHS CUBIC FEET OF RUBBLES.

Executed similar works for Buildings, Transports, Supply of Metal Aggregate and Excavation of Foundation.

———:o:———

Specialists in QUARRYING, SUPPLY OF CHISEL AND HAMMER DRESS STONES, AND CONSTRUCTION OF STONE MASONRY.

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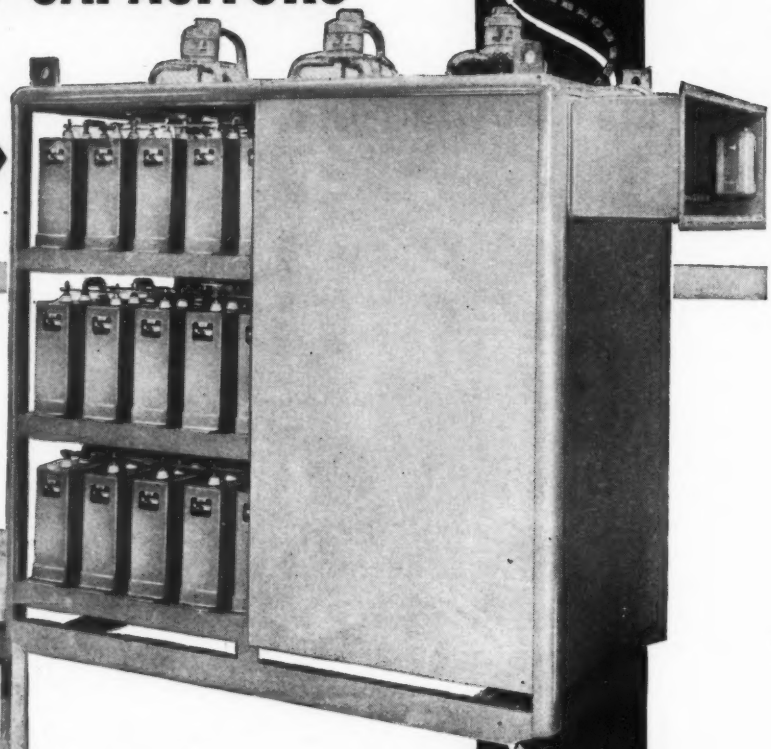
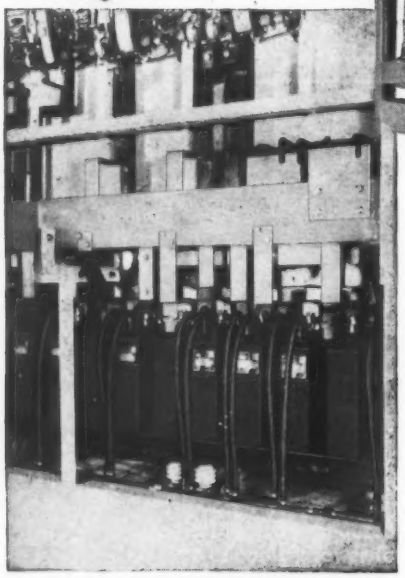


Hunt's Water Cooled Medium Frequency Capacitors. Part of bank for induction Heating Equipment. Capacitor units of 320kVAr, 1600 volts, 3000 cycles. *(Photo by courtesy of Garringtons Ltd., Induction Heating Division).*



Power Factor improvement at the work coil is essential in all Induction Heating Equipment, Hunt's Therminol capacitors, air or water cooled cover frequencies from 50 cycles to 10,000 cycles.

An illustrated Bulletin is available on request, quoting reference volume 2, issue No. 4.

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Technical Features of Gandhi Sagar Power Station

By S. MAHODAYA

THE Gandhi Sagar Power Station is located at the toe of Gandhi Sagar Dam on the right bank of the Chambal River. It will have an ultimate installed capacity of 1,15,000 kW with the installation of five units of 23,000 kW each. At present only four generating units each of 23,000 kW capacity are installed to give a firm generating capacity of 48,000 kW continuous or 80,000 kW at 60 per cent load factor. The fifth generating unit is to be installed at a future date.

WATER CONDUCTOR SYSTEM

The water conductor system consists of the intake made up of trash racks and intake gates, the penstock pipes, the spiral casing, the draft tube and the draft tube gates.

The Intake

The trash racks prevent the entrance of debris and trash, large enough to injure the equipment, into the penstock pipes and the intake gates control the flow of water through the intake pipes. The trash racks are in 20 sections for each unit and are arranged in a semi-circular horizontal arch. Each section weighs about $1\frac{1}{4}$ tons and total tonnage for all the five units is thus 125 tons. Fig. 1 is a photograph of the trash rack structures under installation at the Gandhi Sagar Dam.

One penstock gate has been provided for each of the five penstocks. Each gate is 12′-$2\frac{1}{4}$″ wide and 18′-6″ high, weighing about 16 tons. The gates are operated by hydraulic hoists of 45 tons capacity. The lifting time of the gates is 10 minutes and the closing time 2 minutes. The gate can be closed by operation of an emergency push button from the power house, in case of emergency.

One steel stop-log measuring 16′-2″ × 26′-8″ and weighing about 20 tons is provided upstream of the penstock gate. This stop-log can be used on any of the five penstock openings to facilitate maintenance of penstock gates.

The Penstock Pipes

Five penstock pipes have been embedded in the power section of the Gandhi Sagar Dam at 50′ centres. The penstock pipes have a diameter of 15′-6″ at the upstream end which tapers to 12′-4″ at the scroll case and has a total developed length of 130′-8″.

Spiral Casing

The spiral casing of the turbine commences 23′ from the turbine centre line and is rivetted to the downstream end of penstock pipe. The spiral casing together with speed ring of the first three units weighs about 1,10,000 lbs., and consists of sections which are shop welded and stress-relieved by annealing and were assembled, erected and rivetted at site. The plate thickness of spiral casing varies from $\frac{3}{8}$″ to 9/16″ in case of first 3 turbines supplied by M/s. J. M. Voith, Germany and $\frac{5}{8}$″ to $\frac{7}{8}$″ in case of the fourth turbine unit being supplied by M/s. Hitachi Ltd., Japan. The weight of spiral casing and speed ring of the fourth unit is 1,18,900 lbs. The centre line of spiral casing is set at E.L. 1134. The velocity of water in all sections is practically constant, the maximum velocity at 34,000 B.H.P., 149′ head being 18.95′ per second and average velocity being 18.9′ per second. Fig. 2 is a photograph showing the spiral casing in position for one of the Voith units.

Draft Tube

The draft tube is of elbow type and the vertical centre line is located 171′-6″ from the axis of the dam. The draft tube liner weighing 19,000 lbs., is made of $\frac{3}{4}$″ plate steel welded construction and extends upto a region where the mean velocity does not exceed 15.5′ per second. It is provided with an inspection door accessible from the inspection gallery located at E.L. 1118. Drainage of the draft tube is effected by gate valve and piping leading to the dewatering sump, where two bore-hole pumps have been installed for dewatering purposes.

Draft Tube Gate

Two draft tube gates each of size 10′-$8\frac{3}{8}$″ × 12′-$0\frac{5}{8}$″ and weighing approximately 3.5 tons, have been provided for closing each draft tube for dewatering purposes. These gates have been fabricated in the departmental workshop at Chambal.

TURBINES

Vertical shaft Francis type reaction turbines were selected as being the best suited to prevailing local

Fig. 1—Trash racks at G. S. Dam.

conditions. The turbines have the following main characteristics.

1. Name of manufacturer.	M/s. J.M. Voith G.m.b.H., Heidenheim, Brenz.	M/s. Hitachi Limited Tokyo (Japan).
2. Type.	Francis spiral turbines with outside regulation.	Francis spiral turbines with outside regulation.
3. Net head.	149 feet.	149 feet.
4. Discharge.	2,240 cusecs.	2,100 cusecs.
5. Guaranteed rated capacity at a net head of 149 feet.	34,000 B.H.P.	34,000 B.H.P.
6. Full gate output.	22,800 B.H.P. at head of 115 feet.	22,500 B.H.P. at a gross head of 120′
7. Guaranteed maximum efficiencies at a net head of 149′ for output of 29,000 BPH.	92.5%	92%
8. Normal speed.	187.5 R.P.M.	187.5 R.P.M.
9. Specific speed.	65.7 R.P.M.	66.1 R.P.M.
10. Maximum runaway speed.	402 R.P.M.	390 R.P.M.
11. Runner— Material. No. of vanes. Weight. Velocity of water at runner exit (full gate 149′ net head).	13% chromium cast steel. 15 18,000 lbs. 26.5 FPS	13% chromium cast steel. 15 27,500 lbs. 34.5 FPS
12. Shaft. Material. Weight. Diameter.	Siemens Martin steel. 26,400 lbs. 24 inch.	Forged carbon steel. 20,200 lbs. 22-7/8 inch.
13. Gate servomotors capacity.	1,17,000 ft. in. at 286 psi.	1,51,000 ft. in.
14. Governor— type. Capacity. Guaranteed sensitivity.	Velocity type. 78,000 ft.lbs. 1/10%	Velocity type. 1,51,000 ft. lbs. 0.01″ at relay value.

It is interesting to observe that for the Voith turbines one common shaft is provided for both the turbine and the generator. The thrust and guide bearings are supplied by the turbine manufacturers, whereas the generator supplier supplies only the stator and the rotor of the generator. Fig. 3 is a section through one of the German units.

GENERATORS

Three generators have been supplied by M/s. Siemens Engineering and Manufacturing Company of India Private Ltd., Bombay, and the fourth generator is being supplied by M/s. Hitachi Ltd, of Japan.

The Siemens generators are of vertical shaft umbrella type construction with the shaft and bearings being supplied by the turbine manufacturers.

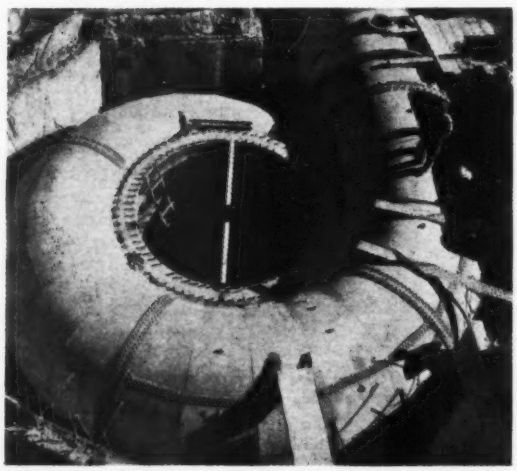


Fig. 2—Spiral casing of Voith Turbine during erection.

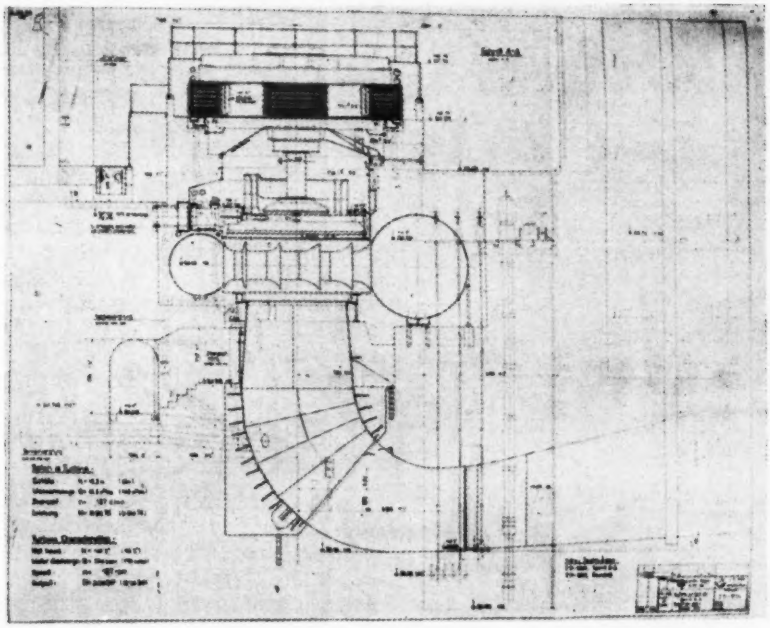


Fig. 3—Section through Voith Unit.

The upper guide bearing is located under the rotor on the bearing bracket and the combined thrust and guide bearing is mounted on the top of the spiral casings.

The special features of the Siemens generators installed at Gandhi Sagar Power Station are electrical shaft system of excitation, magnetic amplifier type of voltage regulation and the neutral isolation. For the fourth generating unit conventional type of excitation and voltage regulation is provided and the neutral is also earthed through an earthing transformer with a resistor in its secondary side.

The other main technical particulars of the generators are:—

	First three Generators	*Fourth Generator*
1. Name of manufacturer.	Siemens Schuckert Werke, Germany.	Hitachi Limited, Tokyo (Japan).
2. Type.	Vertical shaft water wheel driven umbrella type A.C. synchronous generator.	Vertical shaft, water wheel driven umbrella type A.C. synchronous generator.
3. Rating.	11 kV, 1205 amp 3-phase, 50 c.p.s. 23,000 kVA at unity power factor.	11 kV 3-phase, 50 c.p.s., 23,000 kVA at unity power factor.
4. Maximum continuous output at zero leading p.f. and at 11 kV terminal voltage.	18,000 kVA	18,000 kVA
5. Rated speed.	187.5 R.P.M.	187.5 R.P.M.
6. Generator Reactances.		
(*a*) Synchronous reactances (saturated) direct axis	85% plus minus	15% Tol. 90%
Quadrature axis.	54% do	20% Tol. 55%
(*b*) Direct axis transient reactance.		
Saturated.	24.5% do	20% Tol. 45%
Unsaturated.	27% do	20% Tol. 45%
(*c*) Sub-transient reactance.		
Direct axis.	18% do	20% Tol. 33%
Quadrature axis	21% do	20% Tol. 35%
(*d*) Negative phase sequence reactance.	19.5%	35%
(*e*) zero phase sequence reactance.	11%	15%

(*f*)	Resistance of armature winding.	0.0267 ohm.	0.026 ohm.
(*g*)	Resistance of field winding.	0.202 ohm	0.31 ohm
7.	Short circuit ratio.	1.18 saturated 1.07 unsaturated.	1.1
8.	Fly wheel effect of retaining parts.	6.35 million lbs.ft. 2	6.8 million lbs. ft. 2.
9.	Neutral earthing.	Isolated neutral grounded through a lightning arrester.	through a 15 kVA 10000/220 volts transformer.
10.	Maximum run-away speed	402 R.P.M.	390 R.P.M.
11.	Voltage regulator type.	Magnetic amplifier type.	Rheostatic type.
12.	Weight of generator rotating parts.	56,700 kg.	87,550 kg.
13.	Weight of complete generator.	1,13,000 kg.	Details not available.

Fig. 4 is a photograph showing the rotor of a German Unit already installed and the stator being lowered into position.

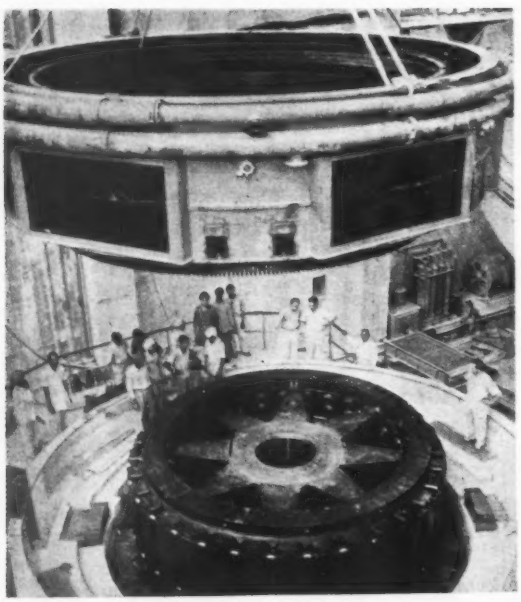


Fig. 4—44 ton completed Stator being lowered on foundation.

STEP UP TRANSFORMERS

The main step-up transformers for all the four units have been supplied by M/s. Mitsubishi Electric Manufacturing Co., Japan. They are form-fit shell type construction and oil immersed, forced oil water cooled type with external heat exchangers, suitable for the outdoor service. Transformers are located in the outdoor switchyard and each bank of 3 single phase transformers is connected directly to each generator by means of 3 single core P.I.L.C., 11 kV 0.6 sq. inch cables per phase, taken in 3-phase trefoil formation through cable spreading room and power cable tunnel. The high voltage winding is star connected with the neutral being solidly grounded and the low voltage winding is connected in delta.

HIGH VOLTAGE SWITCHGEAR AND CONTROL ROOM EQUIPMENT

M/s. G.I.E., Italy, have supplied the outdoor high voltage switching equipment and the generator control panels consisting of a composite 3 Desk Control Board for 3 generator transformer units, a composite unit of 3 panel boards for protection and metering of generator transformer units and a composite unit of 4 panel boards for the 132 kV outgoing line and the bus coupler switchgear.

The following protective relays have been installed on the protection panels of the generators and 132 kV switchgear .

GENERATOR CONTROL PANEL

Three	Single phase differential relays for protection against internal faults (Generator-Transformer differential).
Three	Single phase differential relays (Generator differential protection).
Three	Single phase inverse and definite time over current relays for Generator over current protection.
Three	Single phase inverse and definite time over current relays for 132 kV over current protection.
One	Single phase A.C. over voltage relay.
One	Single phase over frequency relay.
One	Master tripping relay.
One	Single phase relay for generator field ground alarm.

CONTROL PANEL FOR 132 kV OUTGOING LINE AND BUS COUPLER SWITCHGEAR.

On the 132 kV outgoing feeders, the following protective relays have been installed:

One	set of distance relay for both earth and phase faults.
One	wattmetric relay for parallel feeder protection (for Ujjain feeders).

Three single phase inverse and definite time over current relays for Kota feeder.
One inverse and definite minimum time earth fault relay for Kota feeder.
One master tripping relay.

On the Bus Coupler Panel, the following protective relays have been provided:

Three single phase inverse and definite time over current relays.
One inverse and definite time earth fault relay.
One set of differential relays for the 132 kV bus bars protection.
One master tripping relay.

11 kV STATION SERVICE TRANSFORMERS AND SWITCHGEAR

Two station service transformers each of rating 3000/2500/500 kVA, 11000/11000/400 volts, along with the connected 11 kV switchgear have been installed at E.L. 1144 floor under the service and erection bay. These transformers, supplied by M/s. Kamani Engineering Corporation, Bombay (manufactured by M/s. Ansaldo San Giorgia, Italy) are directly connected to generator terminals of units one and two through only an isolating switch. One more transformer of 3000 kVA will be provided along with the fourth generating unit. These three transformers thus cater 7.5 MVA at 11 kV for the local and rural distribution feeders from Gandhi Sagar. The 11000 volt secondary winding of 2500 kVA rating is star connected with neutral solidly earthed and is connected to 11 kV switchgear supplied by M/s. Brush Exports Ltd., Bombay.

The 11 kV switchgear comprises of one seven panel, totally enclosed, floor fixing, air insulated, vertical drop down horizontal drawout type, metal clad switchboard suitable for operation of the above two transformers and arranged for the control of two incoming feeders, one bus section unit and four outgoing feeder units.

The 11 kV oil circuit breaker is of 400 amp., capacity and having a rated rupturing capacity of 100 kVA. The switch board is equipped with castel key interlocks, metering equipment with current transformers, potential transformers and the following protective relays.

(i) Inverse definite minimum time overload relays.
(ii) Unrestricted definite minimum reverse time earth fault relays.
(iii) Instantaneous restricted earth fault relays.

The 500 kVA low voltage windings of the two transformers are connected to the 400 volt station service distribution switchgear supplied by M/s. Siemens Engineering and Manufacturing Co., Bombay.

In addition to the above two station service transformers, one 500 kVA, 11000/400 volt station service transformer supplied by M/s. Electroputri of Rumanian People's Republic, Rumania, is also located at E.L. 1144 floor in a niche in the downstream wall of the power station opposite unit No. 3. This is connected to the third generator terminals and the low voltage side directly feeds the third unit auxiliary distribution board which in turn is interconnected to the 400 volt switchgear with suitable electrical interlocks. The arrangement is such that the distribution board can be fed from any one of the three station service transformers under emergency conditions.

230 VOLT STATION BATTERY

The Station Battery is of 230 V, 200 ampere hour capacity and comprises of 115 cells arranged in series and located in the battery room at E.L. 1170 floor. The battery supplies the solenoid for operation of 132 kV oil circuit breakers and also the D.C. trip circuit of the relays, signal lamps and emergency lighting.

BATTERY CHARGING EQUIPMENT

This equipment manufactured by M/s. Hackbridge and Hewittic Rectifiers Ltd., England, has been supplied by M/s. Steam and Mining Equipment Ltd., Calcutta and comprises of two sets of rectifiers for quick charge and trickle charge, necessary transformers, incoming and outgoing circuit breakers, meters, relays change over switches, etc. The D.C. panel boards are located in Station Service and D.C. Room at E.L. 1170 floor.

AIRCONDITIONING AND VENTILATION SYSTEM

All the rooms at E.L. 1170 floor except the battery room will be airconditioned with an airconditioning plant of about 37.5 tons refrigeration capacity, to be located in the airconditioning plant room at E.L. 1170 floor.

The main generator hall, auxiliary room at E.L. 1144, cable spreading room and station transformer room will be provided with water cooled, forced air ventilation system. Ten air changes have been provided for the generator hall and six air changes in all other rooms.

FIRE PROTECTION SYSTEM

The main generators have been provided with an automatic carbondioxide fire protection equipment. For other equipment in the power station portable C.T.C. type fire extinguishers of ½ gallon capacity have been installed at strategic points.

For the oil fire risks associated with transformers and oil storage rooms, the Mulsifyre System or Fractional Water Spraying System of fire protection is proposed.

COOLING WATER SYSTEM

Cooling water for generators, outdoor transformers,

turbine bearing, etc., is taken from a common 14" diameter main header located in the auxiliary room at E.L. 1144, where one set of Duplex strainers tap raw water from each of the penstocks 1 to 4 and feed into the 14" diameter common header running along the full length of power house building. From this main header, cooling water pipes are tapped for each generating unit and one 8" diameter line is taken to outdoor switchyard for supplying cooling water for power transformers.

GROUNDING

An extensive grounding mat composed of stranded copper wire of 0.5 sq. inch section has been laid in the power house sub-structure, draft channel and in the switchyard area. All the electrical equipment of power station and switchyard are connected to the grounding mat at suitable places to obtain an efficient and sound earthing.

COMPRESSED AIR SYSTEM

One "Demag" compressor of 500 cft. capacity will be installed at E.L. 1144 floor in the auxiliary room up-stream of unit No. 5. Four inch and two-inch diameter main and service lines with suitable outlets and valves are installed at convenient places on different floors to facilitate use of pneumatic tools in all locations of the power station.

CONCLUSION

Provision has been made in the power station for installing fourth and fifth units along with control and protection panel for generator and future 132 kV feeders. In the outdoor switchyard also sufficient space has been reserved for installing step-up transformers, switchgear and for future feeder bays associated with the future units.

(Continued from page 16)

CONSTRUCTION FEATURES OF GANDHI SAGAR DAM

the dam. The draft tube is a heavily reinforced concrete structure. The formwork of this is complicated on account of its changing shape from a circular section in the horizontal plane at the distributor to a rectangular section in the vertical plane at its exit. The substructure is cast leaving suitable ledge for the scroll case. The scroll case is then erected and held down in position by racks and hold fasts to prevent both from floating or collapsing when it is being covered over by concrete. Above this concrete is then erected the generator support which is a heavily reinforced concrete structure. Each of the substructure in the Gandhi Sagar Power Station contains 1,25,000 cft of concrete and 45 tons of steel.

(Continued from page 20)

LAUNCHING OF PRECAST PRESTRESSED PIPE ON BRIDGE OF KUNU SYPHON

Rs. 84,000 the allocated cost of launching comes to Rs. 21,000 which makes a total of Rs. 37,500/- adding the expenditure of Rs. 16,500/- on labour involved in the entire operation. Expenditure involved in doing the entire pipe in cast in situ would have required an enormous amount of timber staging casting about Rs. 72,000.

Thus it is clear from the above that the launching operation has effected economy in addition to allowing the work to go on uninterrupted during floods etc. Due to the unit being cast on ground, it affords a greater facility for laying out and for inspection of cables. The progress of execution is accelerated, as the work on precast unit as well as cast in situ unit can be carried out simultaneously in different spans and the output is doubled.

There are other advantages also of this operation. By avoiding the concrete to be cast in situ where staging for a height of 80′ was involved accidents which might have occurred during the laying of concrete are completely avoided. Quite a good number of manpower would have been necessary for preparation and maintenance of staging etc. against which entire launching operation could be handled by hardly a dozen khalasis and an experienced supervisor. It also does away with the enormous quantity of the timber materials required for the staging and where, considering its height, it would have required greater care to put up a safe and sound staging.

(Continued from page 30)

CIVIL ENGINEERING WORKS OF THE GANDHI SAGAR POWER HOUSE

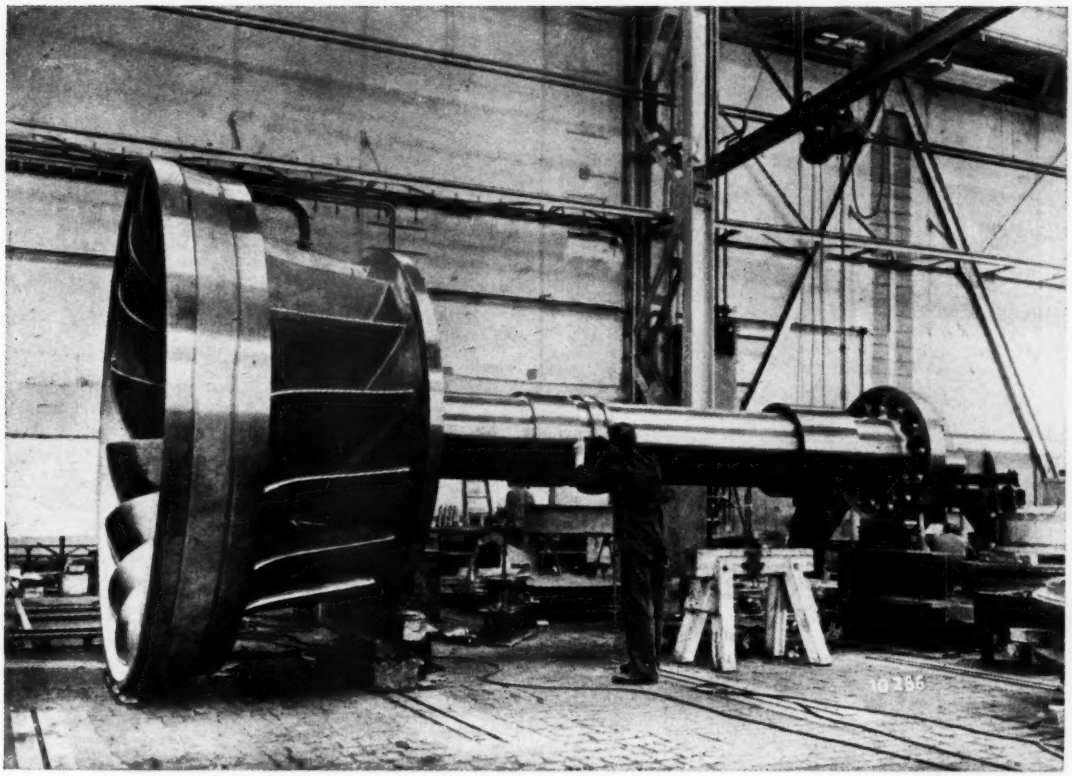
the beginning of the each working season as the foundation of machines are the lowest than anywhere for the dam. Added to it, the time was cut short than otherwise necessary.

CONCLUSION

The main designs for the reinforcement of draft tubes, machine foundations and the framed structures of the Gandhi Sagar Power Station were obtained from the Central Water and Power Commission, New Delhi and minor designs were done at site.

A special feature of construction is that the entire construction of the power house building was executed departmentally except the marble mosaic flooring which was let out on contract to a specialist firm in that line.

The completion of the power station capable of generating 80,000 k.W. of power at 60 per cent load factor which is to be inaugurated by our beloved Prime Minister, stands as a symbol of prosperity and plenty to both the States of Madhya Pradesh and Rajasthan.



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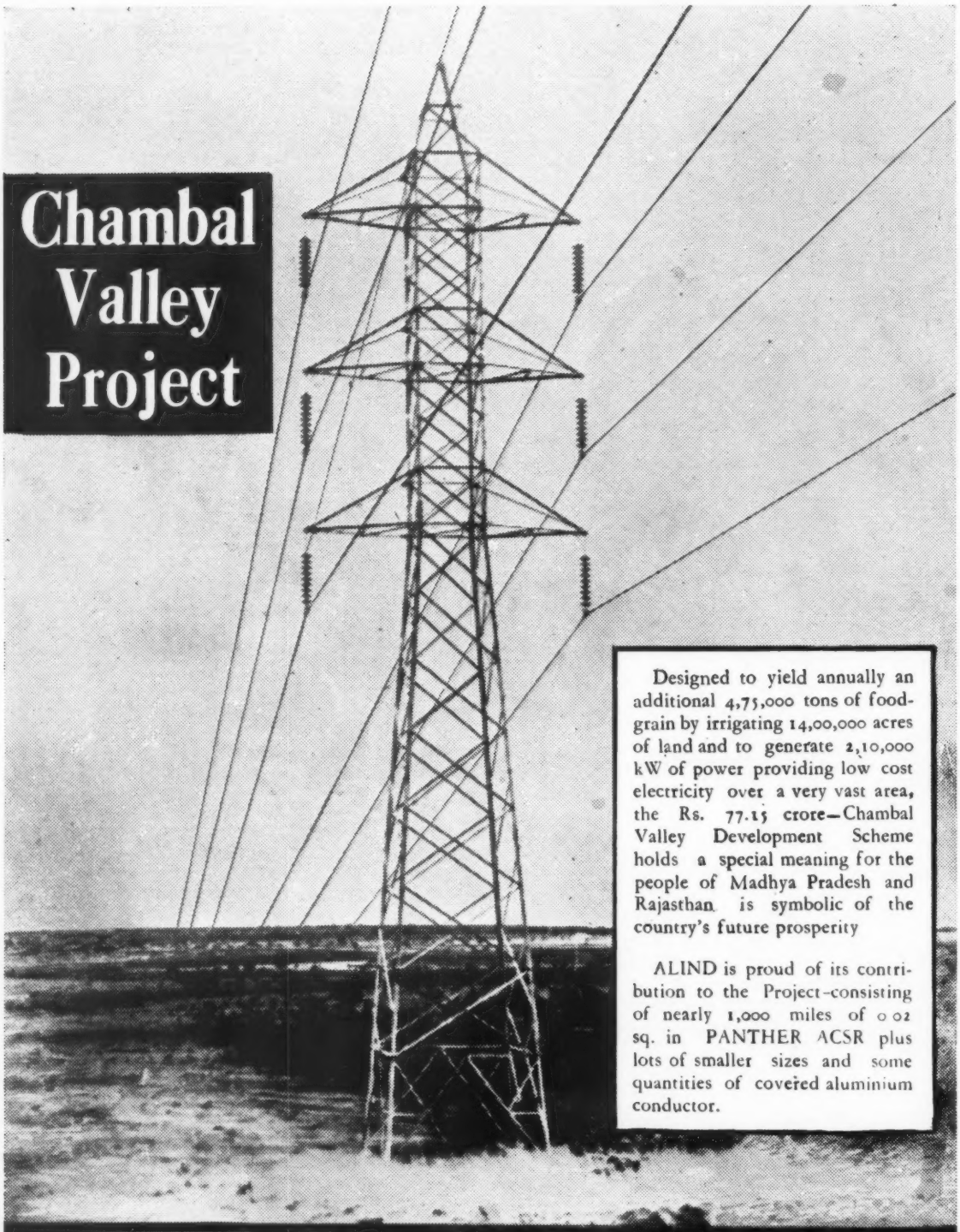

Chambal Valley Project

Designed to yield annually an additional 4,75,000 tons of food-grain by irrigating 14,00,000 acres of land and to generate 2,10,000 kW of power providing low cost electricity over a very vast area, the Rs. 77.15 crore—Chambal Valley Development Scheme holds a special meaning for the people of Madhya Pradesh and Rajasthan is symbolic of the country's future prosperity

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Installation of Penstock Pipes at Gandhi Sagar Dam

By N. S. GAHARWAR

THE penstocks installed at the Gandhi Sagar Dam will supply water from the Gandhi Sagar Reservoir to the five Francis reaction turbines of 34,000 h.p. each of which will drive a vertically mounted generator of 23,000 kVA capacity.

The hydraulic head available for driving the turbines varies from 125 feet to 185 feet. Each of the five penstocks is provided with a gate at its entrance on the upstream side for controlling admittance of water into the penstocks.

Suiting to the site conditions, inclination of a penstock to the horizon has been taken as 30°. With this gradient the axial length works out to 130'-8". The elbow or the bend portion of the penstock has been designed to the extent to have minimum frictional losses due to eddy currents in the conduit. The minimum and maximum velocities of flow of water in the penstocks are within the limit of 10-15 feet per second admissible for medium head.

From the design considerations, thickness of steel plate for penstock works out to 9/16" and adding 1/16" to allow for corrosion a thickness of $\frac{5}{8}$" (i.e., 16 mm) has been adopted. For the bell-mouth portion, upto a length of 40 feet in the upstream side of the pipe, pressure is considerably low and as such, thickness of 9/16" (i.e., 14 mm) has been provided.

Diameter of a penstock is based on the quantity of water passing through it at the rated net head of the turbine, to generate the rated horse power at the station efficiency (expressed as a fraction). The rated horse power of the Francis reaction turbine at Gandhi Sagar Dam is 34,000 H.P. at 149' net head and station efficiency is taken as 0.875. With these values the discharge amounts to 2,240 cusecs. Velocity of flow in penstock at a net head of 149' is 12.23' per

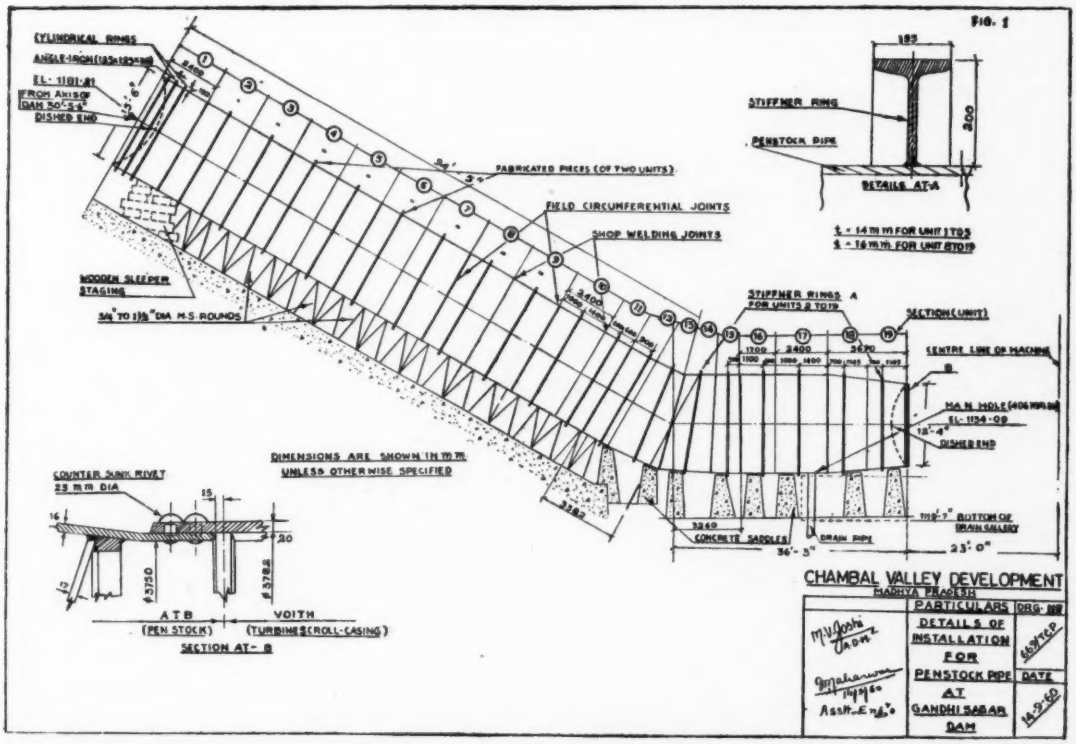


Fig. 1.

Fig. 2—Different stages in the erection works of Penstock pipes in progress.

second. As such the required area of cross-section of penstock is 189 sq. ft., whence the economical diameter of penstock works out to 15′-6″. The downstream end of the penstocks have to be of 12′-4″ diameter in order to secure a butt strap on it for connecting with the scroll casing of the Francis turbines.

Orders for supply and installation of penstock pipes to be erected at Gandhi Sagar Dam site were placed through the Directorate-General of Supplies and Disposals, New Delhi on M/s. Saith and Skelton (P) Ltd., New Delhi, representing the Italian Firm M/s. Acciaieria E. Tubificio di Brescia 'A.T.B.', Brescia (Italy), since none of the Indian workshops, viz., Tungabhadra or Maithon could undertake the fabrication of the penstocks for want of steel plates in our country. By importing the penstocks, a minimum period of about a year was saved in their procurement.

In spite of the Suez Canal crisis the supply of penstocks was received in time by routing the consignment round the Cape of Good Hope.

Penstocks were received at site in half shells each about 8 feet long. They were welded at site, both for longitudinal as well as circumferential joints. Fabricated pieces of two units were lowered on to the concrete saddles and field welding for the circumferentail joints between two such units was carried out after proper alignment. Necessary points and lines for alignment are shown in Fig. 1, wherein various sections (units), concrete saddles, wooden sleeper staging, etc., are also shown. Fig. 2 shows the different stages in the erection works of the penstocks under progress.

Penstock pipe is of welded steel plate construction except for the flanged connections at the downstream end. Each of the penstocks is fabricated in 19 sections (or units) with 18 stiffner rings one in each section except in the first section where two anchor rings (cylindrical in nature) and one angle iron ring at the inlet end have been provided. The stiffner ring is of 'T' section which is classified under Italian Standard as $\frac{1}{2}$ I 40 nP. The internal diameter of the pipe is 4,725 mm (15′-6″) for the first 17 sections tapering to 3,750 mm (12′-4″) diameter at the outlet and thus forming a frustrum of a cone of axial length 3,676 mm (12′-1$\frac{3}{4}$″). First five sections are 14 mm thick and the rest 16 mm thick. Sections 12, 13, 14 and 15 form an elbow of 30° inclination. Sections 1 to 11 are straight and 15 to 19 are horizontal. The total developed length of the pipe is 41,345 mm (135′-7$\frac{3}{4}$″) and total weight of the material supplied is about 450 metric tons. Steel plates are of Martins Siemens Steel Aq. 42 type as per Italian UNI Standard No. 815 with ultimate tensile strength varying from 60,000 to 71,000 p.s.i.

(Continued on page 57)

Installation of Sluice and Crest Gates in the Gandhi Sagar Dam Spillway

By K. G. S. IYENGAR

THE spillway of the Gandhi Sagar Dam has been designed for flood discharge of 4,84,000 cusecs, partly through sluices and partly over the crest. There are in all 9 regulating sluices and 10 crest bays in the spillway portion and with maximum reservoir level at E.L. 1312.00, the sluices will discharge under maximum head of 106 feet (E.L. 1312.00—E.L. 1206.00).

THE MAIN FEATURES OF THE SPILLWAY ARE:

(1) Average bed level of river	E.L. 1120.00
(2) Sill level of the sluices	E.L. 1193.50
(3) Size of each sluice	10′ Wide × 25′ height
(4) Sill level of the crest	E.L. 1284.00
(5) Size of the crest between piers	60′ Wide × 28′ height
(6) Full reservoir level	E.L. 1312.00
(7) Maximum water level	E.L. 1312.00
(8) Minimum draw off level	E.L. 1250.00
(9) Road level	E.L. 1324.00
(10) Top of parapet	E.L. 1328.00
(11) Gross storage capacity of reservoir	6.85 M.A. ft.
(12) Live storage capacity of reservoir	6.18. M.A. ft.
(13) Dead storage capacity of reservoir	0.67 M.A. ft.

REGULATING SLUICE GATES

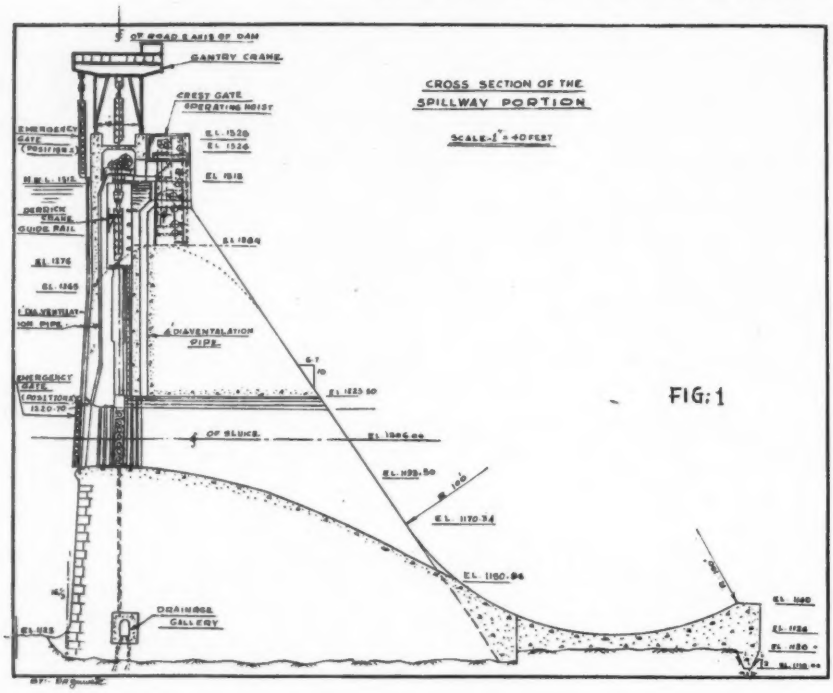
Sluice barrels have been constructed strictly according to hydraulic requirements. Entrance has been bell mouthed to give smooth entry and to obtain very high co-efficient of discharge. The centre line of suspension of gate coincides with dam axis which is also the centre line of the roadway. A few feet upstream and downstream of this gate, the sluice barrel has been lined with steel plate liners. The sluice gate is of fixed roller type with main girders formed of rolled steel sections. Normally the gates will be in either fully opened or fully closed condition. They are, however, designed to be subjected to, occasionally, partially open conditions to regulate the discharge through sluices. This contingency will arise when discharge through turbines is insufficient for irrigation.

The gate leaf is fitted with guide springs on all the four corners and two of the seven flat rollers on one side are flanged to prevent any lateral shift, during its operation. All the field assembly of the gate leaf is by rivetting, 1380 rivets being involved in each gate. Each sluice gate including links hook block and chain, weighing approximately 36 tons, is individually operated by a winch, electrically driven and installed at E.L. 1313.00. Each winch has a lifting capacity of 55 tons. In case of failure of electrical energy, there is provision for hand operation. The top and bottom position of the gate is confined by limit switches, the bottom edge of the raised gate being at E.L. 1218.83. Total time required to completely lift the gate does not exceed 45 minutes, when electrically operated and 560 minutes, when hand operated. These gates can be removed by 75 tons capacity gantry crane moving over parapets, in case of major repairs. A chamber of suitable dimensions in each gate slot is, however, provided above E.L. 1276.00 for maintenance purposes. A pipe derrick is provided in each chamber for inserting and removal of links connected to the chain, during operation (Fig. 1).

Sluice emergency gates

At the entrance of each sluice, at distance of 4861 mm. from dam axis, there exists an emergency gate whose clear opening is 16′-10½″ wide and 31′-11″ high with the sill kept at E.L.1192.32. The emergency gate is also of fixed roller type with main girders formed of rolled steel sections. There is only one gate leaf, with guides and armatures embedded in all the 9 sluices. The emergency gate is required to be lowered, whenever there is breakdown in sluice gates and when these gates are removed to their chambers for replace ment of rubber seals, and routine maintenance.

The emergency gate will be raised and lowered by the 75 ton gantry crane moving over dam parapets. A special spreader assembly (lifting beam) provided with the crane for operating the gate, permits connection and release of gate hook under water. The gate is normally stored on the left flank in a suitable concrete chamber. The emergency gate leaf weighing approximately 55 tons is in 4 pieces and the field assembly is accomplished by fixing G. I. bolts and nuts. The gate leaf is fitted with guide shoes on all four corners to enable the gate to roll exactly on the track rail, without any lateral shift. The emergency gate is provided with arrangement of a sliding valve for compensating water pressure, prior to raising



operation. This eliminates the necessity of providing separate by-pass pipe for equalising the pressures. The lowering and raising of the gate takes 30 minutes approximately.

Air Vents

In order to avoid formation of vacuum and assure smooth operation of sluice and emergency gates, air vents 4′ and 1′ diameter have been provided just downstream of both sluice regulating and emergency gate slots, respectively. The 4′ diameter air vent starts from the crown of sluice arch at E.L. 1223.50 and is connected to atmosphere at the downstream face of pier at E.L. 1306.00. The 1′ diameter air vent starts from roof of the bell mouth at E.L. 1220.70 and is connected to atmosphere through winch house at E.L. 1313.00.

Seals

The sealing for water-tightness in sluice gates is on the upstream side whereas in emergency gate, it is on the downstream side and are quite different from each other. The side and top sealing in sluice gate is obtained by stainless steel strip sliding securely on steel seat. For its proper functioning, soft rubber strip, one face flat and other face tapered, with curved flat iron is fixed onto the seal with countersunk G. I. bolts and nuts. The bottom seal is flat rubber strip flexible enough to make the bottom, water-tight under the load of the gate.

The side and top sealing in emergency gate is obtained by means of hard rubber seals pressing against steel seat under hydraulic pressure. The bottom seal is the same as the one provided for sluice gate.

CREST GATES

The 10 crest gates are also of fixed roller type with main girders formed of rolled steel section. The clear opening of the crest is 60′ wide, 28′ high, without any provision for free board. The crest gate will be most of the time exposed to sun, partly or wholly. As such, for safety and easy operation of the gate on account of expansion, rocker shaft with rocker plate have been provided on the gate, mounted on the bogies on all the four corners.

Each crest gate, weighing about 72 tons is individually operated by two winches, one on either side in the piers at E.L. 1318.00. Out of these two winches, one is electrically operated and the other mechanically coupled to it through a shaft supported by bearing blocks at E.L. 1319.75. Each winch has a lifting capacity of 36 tons. In case of failure of electrical energy, there is provision here also, for hand operation. The top and bottom position of the gate is confined by limit switches, the bottom edge of the raised gate being limited to E.L. 1308. 50. The gate and drives are proportioned for a normal water head of 28′ and over toppling is not taken into consideration. Total time required to completely lift the gate does not exceed 30 minutes when electrically operated and 500 minutes when hand operated. All field assembly of the gate leaf is by rivetting and 5398

rivets are involved in each gate. The general arrangement of the gates and hoisting mechanism is shown in Fig. 2.

Seals

The sealing arrangement is generally the same as the one provided in the sluice emergency gate. Sealing on the top of the gate is, however, not provided as the top of the gate will be at E.L. 1312.00.

Gantry Crane :

An electrically operated gantry crane whose main hoist capacity is 75 tons and auxiliary hoist capacity is 35 tons, is provided for the lifting operations of these gates. This moves on a 18′ gauge rail track on parapets at E.L. 1328.00 right along the dam from one end to the other. The electrical contact line consists of brackets with cup-shaped insulators mounted, and round copper conductors suspended with a span of six meters. This is provided on the outside face of the downstream parapet wall. This crane is used both for operation of sluice emergency gate and penstock emergency gate (stop-log gate) by means of the main hoist The auxiliary hoist is provided for taking out the sluice regulating gate leaf in the spillway portion (weighing approximately 32 tons) and penstock gate leaf in the power dam portion, weighing approximately 35 tons, from its chambers, in case of major repairs. The crane is normally stored in a housing on the left flank.

ERECTION OF SLUICE AND EMERGENCY GATES

Messrs. M. A. N., West Germany, were given the contract for supply and fabrication of sluice gates, emergency gates, crest gates and gantry crane. All these materials were received at site, well in time. Notwithstanding this, it was decided to take up the entire erection, departmentally. For a work of this magnitude, involving erection of about 2000 tons of fabricated materials, gangs of skilled workmen conversant with such heavy erections, were essential. Since such gangs were not readily available at site, they had to be recruited from Malabar.

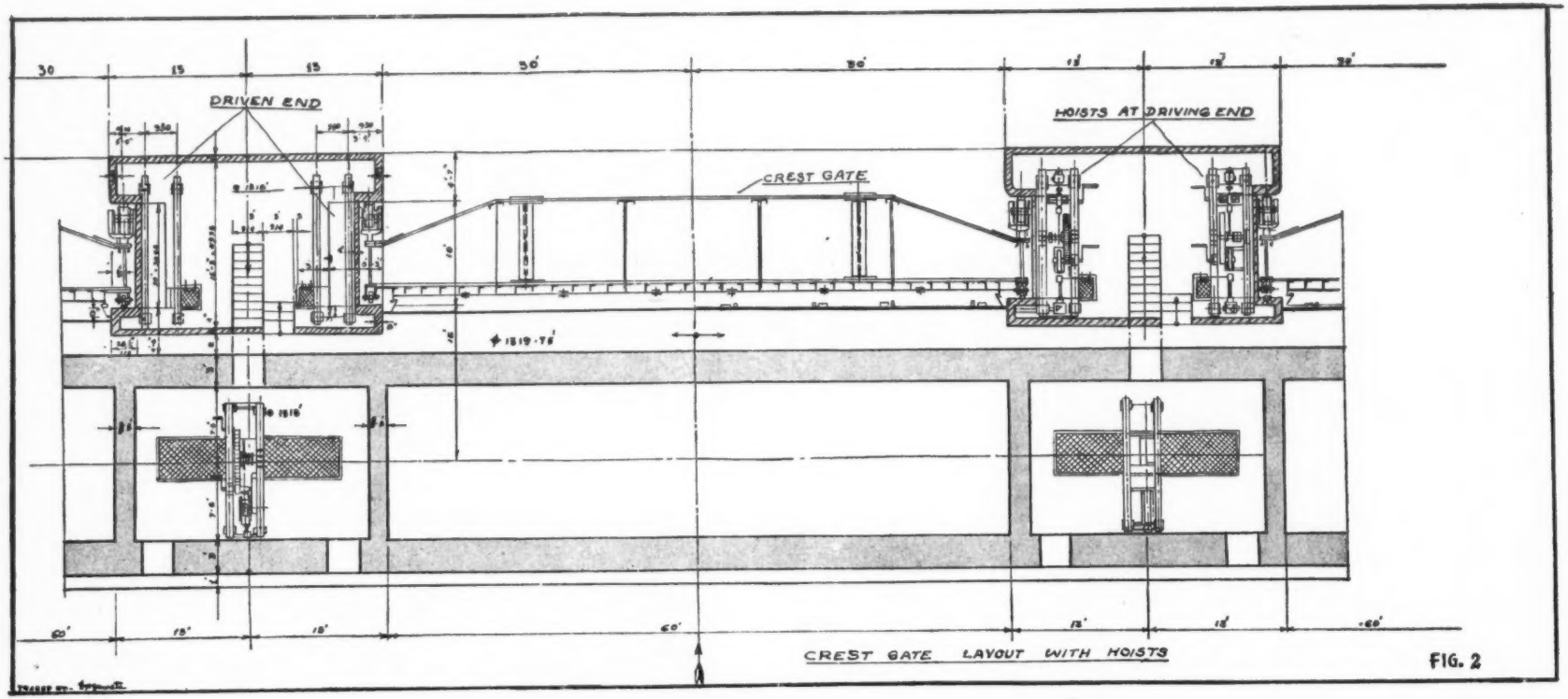
Since the supply of these gates duly fabricated was made by the firm in its entirety and also since the firm was to be held responsible for proper functioning of all the equipment after erection at site, it was considered desirable to obtain the services of their erector for supervision of erection, to be done strictly in accordance with their drawings. Messrs. M. A. N., considering the volume of work, recommended four erectors for the purpose, at a considerable cost, involving considerable foreign exchange as well. It was considered that with suitable skilled staff to work on the erection, it should be possible for us to manage with only one erector and accordingly, the services of one foreman from M. A. N. were secured for supervision of erection. The erection work was carried out successfully and at no time necessity for more than one erector was ever felt. It is no exaggeration to say that the entire erection staff proved their worth in successfully executing the work, that too according to a very tight construction schedule, in utmost difficult circumstances

TRANSPORT AND STACKING OF PARTS

To handle approximately 2000 tons of steel comprising of sluice gates, emergency gates, crest gates and gantry crane, a separate yard 300′ long and 100′ wide, was made. The parts were removed from main stores, with the help of crawler crane and heavy duty truck-trailor. These parts were then properly stacked for easy, methodical handling for subsequent despatch to the site of placement. Since the approach to the dam proper from the upstream side was not possible for a heavy duty crane, on account of silt deposit, the transportation of parts to the site of placement had to be achieved by means of radial aerial cableways only. There are two such cableways, one of 10 tons capacity of upstream face and the other five tons capacity on the downstream face. Since the erection of the gates was mostly on the front face of the dam, the ten ton cableway was very handy, particularly for the transportation of the sluice gate leaf, in parts, the maximum weight of each piece being approximately eleven tons.

The first step in the erection of these embedded parts consisted in alignment and marking out centre lines. The sill beam and bed liners, maximum weight of each being approximately 1½ tons, were taken to the dam from the upstream side, and lifted by shear legs from the river bed at E.L. 1120.00 to the site of placement at E.L. 1193.50. This method saved the valuable hours of cableways which was in fact required for the concreting work. The sill beam and the bed liners were properly assembled with adequate supports from all sides. This was placed at E.L. 1193.50, aligned and levelled. After final checking, the supports were made quite rigid by wedging and welding. These were then grouted with rich concrete. The concrete was poured through fourteen 1′ diameter openings in the bed liners and vibrated by pneumatic vibrators through thirty of 3″ diameter openings, also provided in the bed liners. The grout was sufficiently cured and openings were then plugged with steel plates of the same size by welding.

Thereafter the erection of side liners, side seats, top seat with arch and liner, and track with armature was taken up. These parts were transported by cableways to the site of placement. The liners were provided from the sill upto approximately E.L. 1220.00, to resist the high velocity of water flowing through the sluices. After lowering the aforesaid parts in position, the whole assembly was tightened with bolts



CREST GATE LAYOUT WITH HOISTS

FIG. 2

and nuts. The anchor rods attached to the guides and liners were then bolted to the anchor rods in the pockets of the blockouts. Proper alignment was accomplished by giving supports to liners on either side and the whole structure was kept in plumb on all sides. The supports thus given for alignment were welded to keep the structure rigid, in position. In order that there may not be the slightest deformation on account of grouting of these embedded parts, the structure was supported by vertical props of heavy girders and cross channels, duly welded, to make the whole structure rigid. After alignment and final checking, the whole assembly was grouted with rich concrete and vibrated. Since it involved considerable depth and the space was rather narrow, to obtain homogeneous concrete without disintegration the grouting was done bit by bit to a depth of 5'-6', at a time, with the help of suitable chutes. With these supports, not the slightest dislocation or deformation of the embedded parts was possible, while these were being grouted. The completion of erection of the first stage ended with the alignment of the top seat.

Similarly the erection of embedded parts of emergency gate was taken up simultaneously. The sill weighing about 1½ tons was first placed in position by shear legs. Since the sill and guides of emergency gate were on the front face of the dam, suitable platforms were prepared and erected at site to work on the sill and guides (Fig. 3). The sill was aligned properly and then grouted with rich concrete and vibrated. The combined track guide and armature, 43' long, weighing 3½ tons, were to be erected on the upstream face of the dam. The alignment of these involved lot of risks. All possible precautions were taken to avert accidents and the guides were erected and aligned with the help of cross girders, as shown in Fig. 4 and fixed with the help of bolts embedded in the concrete, on the sides. After alignment and final checking, the grouting was done in the same manner as outlined above, in view of the exactly identical conditions existing there also.

The erection work connected with the sluice and emergency gates was done initially in one general shift only. Later, the work was done in two shifts and sometimes in three shifts, to keep up to the target dates. This was essential, as otherwise water could not have been stored during that season. Thus, the first stage erection of gates was completed successfully, in a short period of four months.

The work of assembly of sluice gate leaves, thereafter, was to be taken up on the dam itself, for subsequent lowering in their chambers for storage of water in the reservoir. This work was of a very significant nature, in as-much-as, this had to be achieved during the rainy season itself. The masonry on various blocks of the dam was at different levels, the maximum level being E.L. 1245.00. It was considered that the assembly of the gate leaves could be taken up at E.L. 1245.00 itself, as it was presumed that the flood water would not go beyond this level.

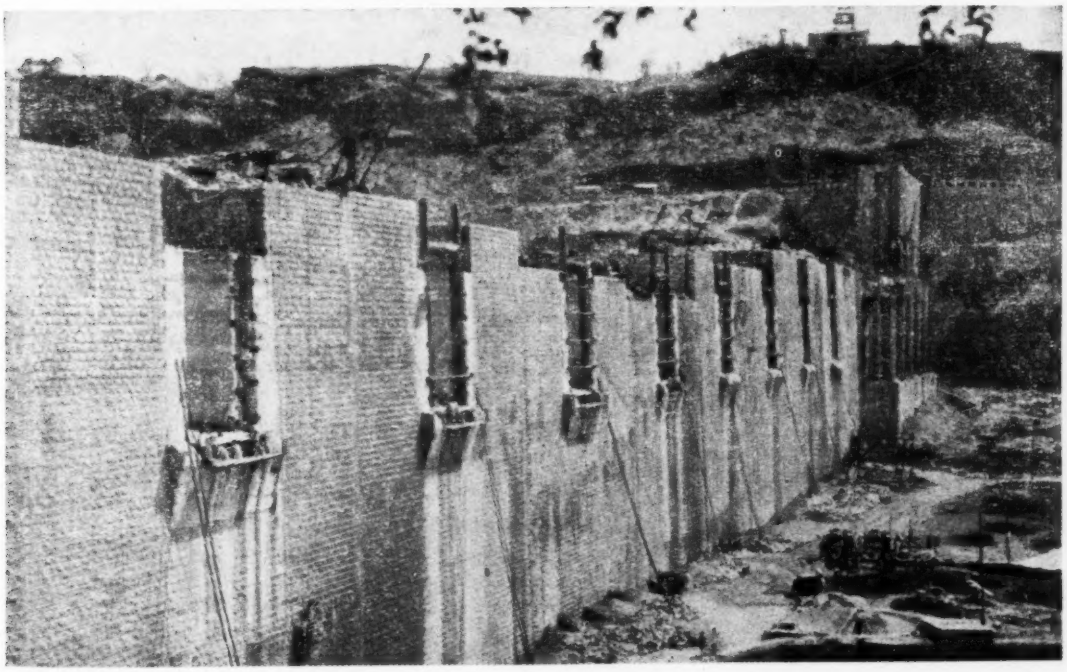


Fig. 3

This, however, necessitated putting up piers on the masonry blocks wherever the levels were low. To expedite this work, piers were put up by concreting as it would give quicker progress. The sluice gate leaf was in three pieces comprising of the central leaf and two bogies, one on either side. The central piece weighed the maximum (approximately 11 tons). There was no other alternative except to take these pieces by the ten ton cableway. Extra precautions were therefore taken in transportation of these pieces, in particular. These pieces were assembled on the dam by hot rivetting.

The assembly of the gate leaves had to be achieved even in the face of the floods in the river and the reservoir level increasing day by day. The gate leaves, for sake of safety in case of high floods, were suitably anchored to the masonry in concrete pedestals. The assembly and rivetting was kept up even during floods. Thus, all the nine sluice gate leaves were got ready duly assembled and rivetted. This was the most difficult and daring task and was achieved with remarkable success. Fig. 5 indicates the erection work in progress during the period when the flood waters were gushing over the dam.

For lowering of 9 sluice gate leaves, each weighing approximately 32 tons, in their respective chambers,

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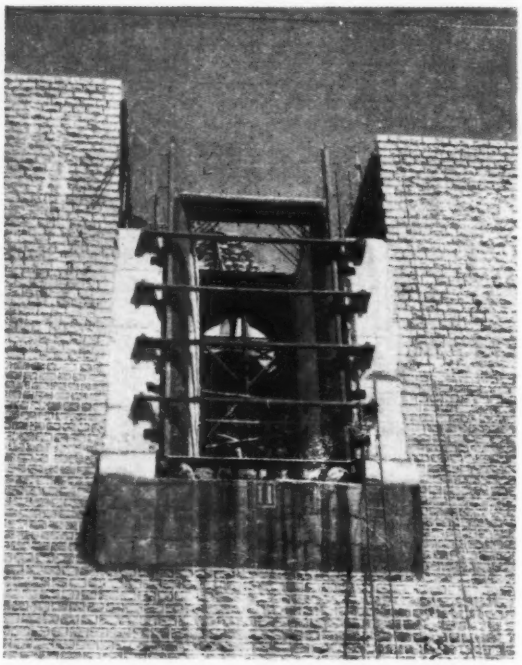

Fig. 4

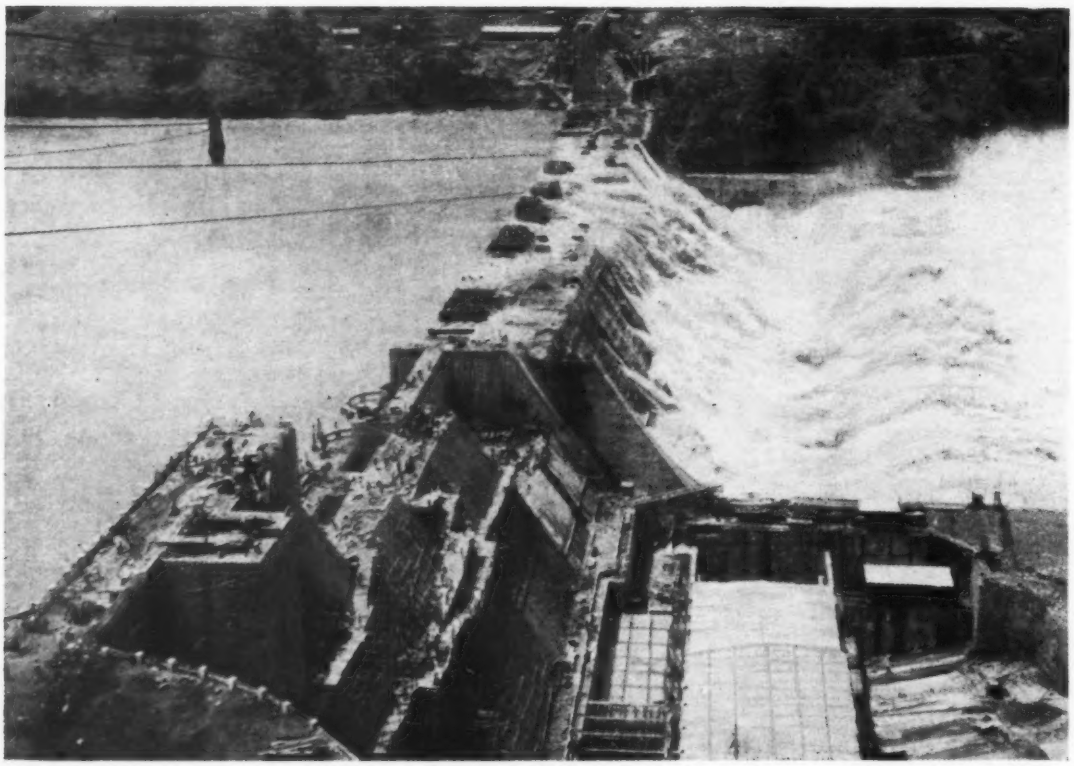

Fig. 5

Special Features of the 23MW 'Siemens' Generators Installed at Gandhi Sagar Power Station

By B. M. BHARATEEY

THIS article describes in brief the special features of the 23 mW generators installed at Gandhi Sagar power station in respect of the excitation system, the isolated neutral and earth fault protection system and the voltage regulator system.

ELECTRICAL SHAFT SYSTEM OF EXCITATION

by Auxiliary Shaft Generator Arrangement

The usual excitation system with directly mounted main and pilot exciter presents the following disadvantages when employed with low speed synchronous generators.

(a) Due to their comparatively low speed, the exciters have large magnetic inertia, resulting in lower response ratio. This is particularly disadvantageous especially in the case of generators feeding into long distance transmission lines, which require high excitation response.

(b) The height of the normal vertical shaft generators is more and consequently the costs for the construction of the power house are appreciably increased.

(c) With low speed generator units, the size of the exciters necessarily have to be larger, and this results in their being more expensive.

Realising the need for a simple and reliable excitation system fulfilling the desired requirements, 'electrical shaft' system of excitation has been developed and patented by Messrs. Siemens Schukertwerke, Germany.

The basic principles of this system are: A three-phase synchronous generator known as the 'auxiliary shaft generator' is mounted directly within the main generator (Fig. 1). The stator of this generator is normally bu lt-in into the upper generator bracket, its rotor being mounted on the rotor of the main generator. This auxiliary shaft-generator is self-excited through an arrangement of exciter-transformer and full wave metal rectifier. The output of the auxiliary shaft generator is fed into the driving motor of the separately and externally installed exciter set by means of a simple cable connection (Fig. 2). It is by virtue of this feature that the system is called the 'Electrical Shaft' system as against the conventional 'Mechanical Shaft' system with the exciters mounted on the extension of the main generator shaft.

As stated in the foregoing paragraph, the auxiliary generator is self-excited through an arrangement of exciter transformer and full wave metal rectifier (Fig. 3) and its field current is made up of a base a.c. component which is independent of the load current and another a.c. component which is proportional to the auxiliary shaft generator load current, the two components being added geometrically. The load independent component is determined by a suitably rated choke, while the load dependent component is determined by the load on the auxiliary shaft generator. The resultant total current of these two components is rectified by the full wave metal rectifier and fed into the sliprings of the auxiliary generator. It is thereby ensured that with increasing load on the auxiliary shaft generator, its field current is also increased automatically, thus maintaining the voltage constant.

During starting up of the generating unit the excitation of the auxiliary shaft generator is initiated by utilising the inherent residual magnetism of its field (Fig. 4). A three-phase condenser bank is connected on the secondary side of the exciter transformer so that it has virtually the effect of being connected in series with the choke. If this condenser bank is tuned to resonance with the choke, the low residual voltage of the machine can be built up to a much higher value across the condenser terminals at resonant frequency. The rectifier which is connected to the exciter-transformer is parallel to the condenser, will then receive the built-up voltage which is ample to overcome the contact resistance of the rectifier and the sliprings. The excitation is thereby initiated.

As soon as the turbine set is started up, self-excitation of the auxiliary shaft generator is initiated at the present speed, e.g. at 40 per cent of the rated speed. At this speed the induction motor driving the separately and externally mounted exciter set is automatically started up and the main generator excitation is rapidly built up to its normal no-load value (as in the case of a normal shunt wound d.c. machine) even before the turbine has reached its rated speed. The main generator voltage is controlled as usual by the high speed voltage regulator. When the generator is

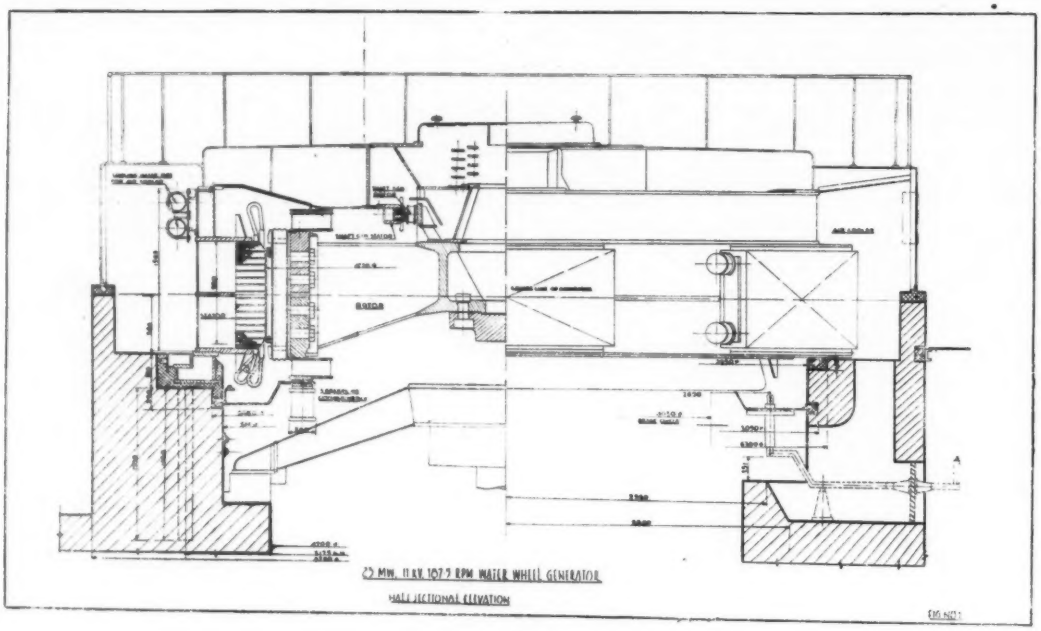

Fig. 1

loaded, increased excitation is automatically furnished through correspondingly increased output of the auxiliary shaft generator to the driving motor of the exciter set, since the excitation of the auxiliary shaft generator is automatically increased by virtue of the load-dependent component of its field current. When the main generator speeds up due to sudden rejection or throw of off-load, the excitation of the shaft generator is so adjusted as to become zero if the frequency rises to over 75 cycles per second. This automatically stops the separately and externally mounted exciter set and consequently, the excitation to the main generator is also cut off. Thus there is no chance of over-voltage appearing at generator terminals due to over speed. (Fig. 5).

The auxiliary shaft generator mounted on the upper bracket of the generator has a rated output of 200 kW at 380 V and short period overload rating of 445 kW at 380 V. Excitation of these sets is by an automatically operating self-excitation circuit with the following ratings.

Voltage	*Current*
54 V	73 A
90 V	122 A

The motor driven exciter set consists of a three-phase synchronous motor with deep bar rotor of 2000 kW rated output at 380 V and 980 RPM and one exciter with the following ratings:

91 kW at	160 volts	continuous
127 kW at	190 volts	
204 kW at	240 volts	short circuit operation 10 seconds

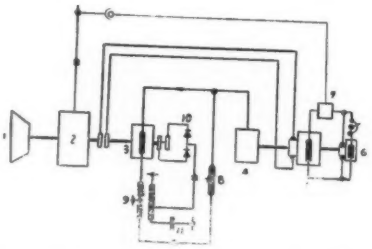

Fig. 2—Single line diagram showing the principle of excitation system with auxiliary shaft-generator and separately installed exciter set. 1 Turbine, 2 Main generator, 3 Auxiliary staff generator, 4 exciter, driving motor, 5 Main exciter 6 Pilot exciter, 7 Voltage regulator, 8 Choke, 9 Excitation transformer, 10 Full-wave rectifier 11 Condenser.

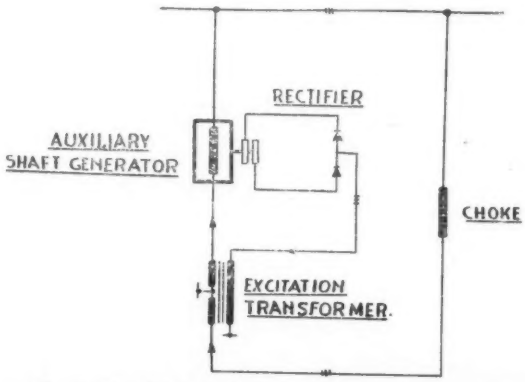

Fig. 3—Simplified single line connection diagram for excitation arrangement of the auxiliary staff generator.

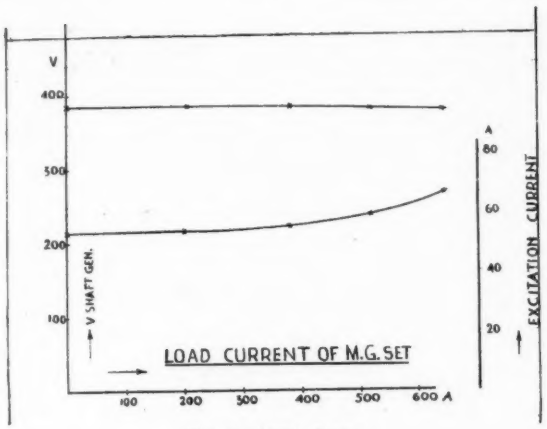

Fig. 4—Load Curve.

Field excitation of these sets is by 2 separate field windings (one for positive excitation and one for negative excitation), which are separately excited by magnetic amplifier voltage regulator.

Summarising, the outstanding features of the Siemens 'Electrical Shaft' system of excitation are:—

(1) The speed of the separately installed exciter set can be selected to obtain optimum electro-dynamic characteristics.

(2) Since the exciters are separately installed and the auxiliary shaft-generator can normally be built into the upper generator bracket, considerable reduction in the installed height of vertical shaft generators can be achieved.

(3) The exciter set automatically runs up to its normal speed and develops the necessary no-load excitation even before the rated speed of the turbine is reached.

(4) The power supply to the exciter set is entirely independent of disturbances, short circuits or voltage break-downs in the supply network.

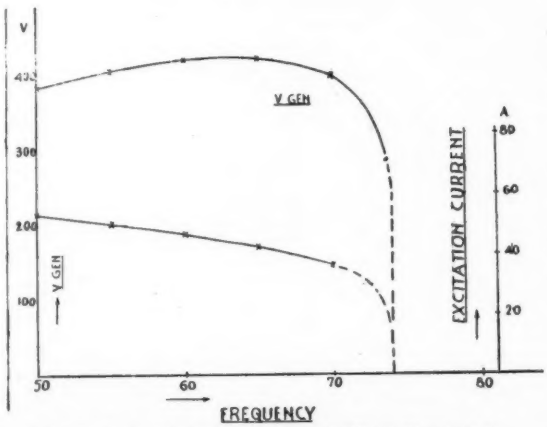

Fig. 5—De-excitation by overspeed. (Shaft Generator).

(5) The arrangement is simple, reliable and requires hardly any maintenance. The short leads between the driving motor of the exciter set and the auxiliary shaft generator require no additional switching equipment, so that erroneous switching due to mal-operation is eliminated.

ISOLATED NEUTRAL AND EARTH-FAULT PROTECTION

With the earthing of the neutral solidly or over a resistance or reactor, a harmonic current flows continuously over the capacitive coupling of high and low voltage sides of the solidly grounded transformers. The magnitude of this current is determined in the first place, by the voltage of the third harmonic and the system capacity, and to a lower extent, by the neutral resistance. This means, however, that a less sensitive adjustment is required for a selective earth-fault protection, i.e., the protective range extends over a smaller part of the machine winding, apart from the fact that the harmonics are undesirable from an operational point of view.

In case of an earth-fault, in the generator with earthed neutral, an earth current of the magnitude of the rated current or more, flows over the point of fault and over the connection of neutral to earth. The differential protection controls this fault in approximately 0.1 second and disconnects the generator from the line. The neutral connection may also be separated by means of a switch, operated by the differential protection. However experience with many large running generators has shown that inspite of the above described measure, burning of the iron laminations in the generator occurred, to a considerable extent than with low earth currents as might arise in case of a free neutral.

For the above mentioned reasons, the Siemens generators are provided with isolated neutral and a stator earthing transformer which is connected to the terminal side of the generator, through fuses. By this process the earth-faults on H. V. side are not transmitted directly to the L. V. side, due to galvanic separation of high and low voltage sides. The occurrence of a displacement voltage on the low voltage side can thus be taken as a criterion for the earth-fault.

The earthing transformer used for this purpose is loaded by means of a resistor and connected to a sensitive d.c. relay over a series resistance. The transformer is of special design and is connected star/open delta/star (Fig. 6). The open delta winding is closed by the above load resistor and the star connected tertiary winding is used for measurement, synchronising, etc.

Voltage Regulating Equipment

The automatic voltage regulating equipment is of magnetic amplifier type. The diagram of connections

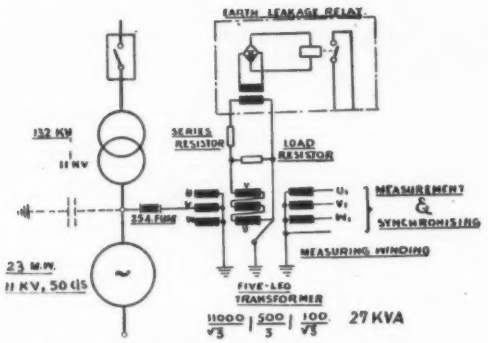

Fig. 6—Earth-fault protection of generator/transformer in unit-system operation.

is shown in Fig. 7 and Fig. 8 is a photograph of the same. A control signal proportional to the deviation in the generator terminal voltage is formed in the voltage comparator which consists of a bridge circuit. The voltage comparator is insensitive to frequency and is fed, via a rectifier in bridge connection and an intermediate transformer, from the voltage measuring circuit. The d.c. output of voltage comparator is used for the control of the two-stage transductor (magnetic amplifier). The input stage consists of a push-pull pre-amplifier which is installed as a self-contained unit in the regulator panel and which also contains adjustable series resistors in the control circuits of the output stages. The two transductor output stages consist of (1) six pairs of transductor elements installed in the bottom of the cubicle and (ii) rectifiers. The positive excitation output amplifier feeds the positive field winding of the exciter and the

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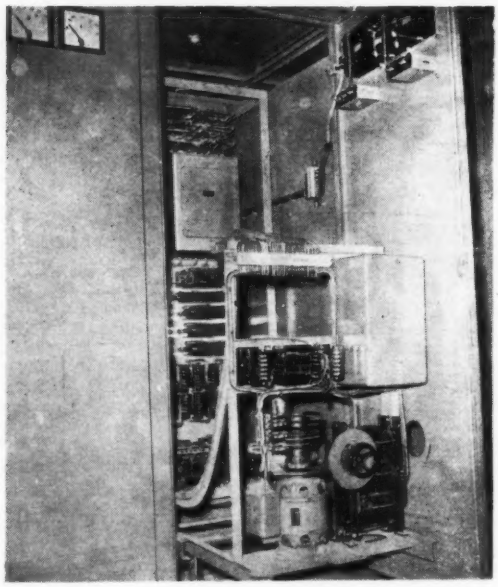

Fig. 8.

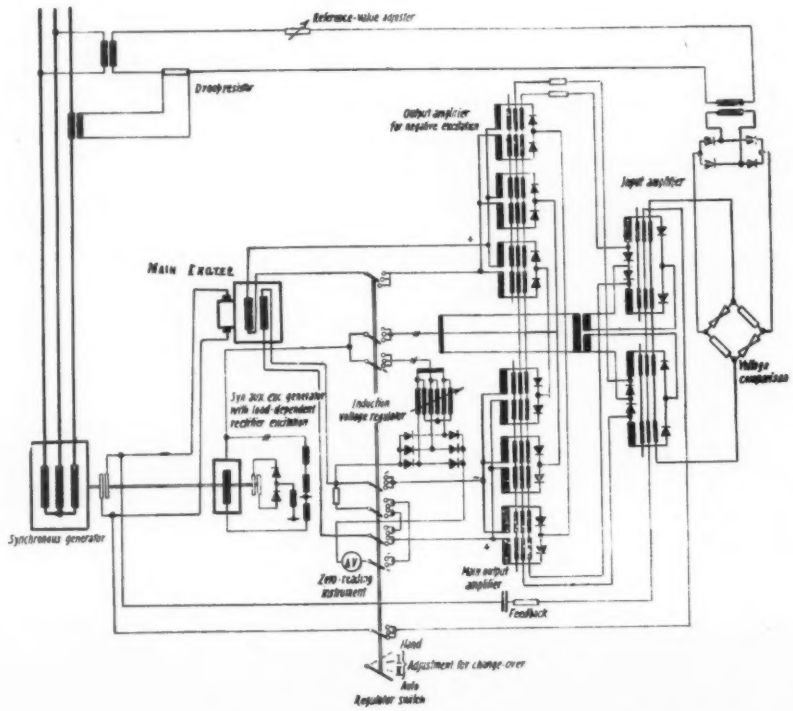

Fig. 7—Synchronous generator with magnetic amplifier regulator. General circuit diagram with "Hand-auto" changeover equipment.

Layout of Gandhi Sagar Switchyard

By O. P. UPADHYAY
and R. V. APTE

THE Gandhi Sagar power station will ultimately have five generators of 23 MVA each. At present only four generators are being installed.

Power will be fed from here to Ujjain and Kota through 132 kV double circuit lines and to Neemuch through a 132 kV single circuit line. The switchyard at Gandhi Sagar power station has, therefore at present four transformer bays: two bays each for Ujjain and Kota feeders, one bay for Neemuch feeder and one bus coupler bay. Provision is also made at the switchyard for the future fifth transformer bay and three spare bays for future extensions.

Figure 1 shows the layout of the switchyard constructed by the side of the draft channel. Fig. 2 gives a view of the switchyard nearing completion. It is 21 meters wide and 168 meters long. The steel structures and the H. V. equipment such as oil circuit breakers, potential transformers, isolators, etc. were supplied by M/s. Galileo through M/s. G. I. E., Italy.

The foundations for the steel columns and pylons were brought up from the river bed using precast R. C. C. rings and stone masonry filling, on which the column foundation block takes the shape of a stopper block. Masonry wall foundations have similarly been brought up from the solid rock up to the rail track, to support the weight of the main set-up transformers. For all other equipment like circuit breakers, current and potential transformers, isolator trestles, etc., reinforced foundation blocks of adequate area have been provided.

Figure 3 shows the single line relay and metering diagram for Gandhi Sagar power station.

The generator-transformer units are connected to the two buses—one main and another duplicate through 132 kV circuit breakers and isolators. The main and duplicate buses are coupled by the circuit breaker installed in the bus coupler bay. The buses are of A.C.S.R. conductor (54/2 9 mm Al. plus 72.9 mm steel) and are spaced 3000 mm apart. Connections to the various equipment are made by aluminium tubes, where rigidity of connection is required for maintaining electrical clearances, and at other places connections are made with all aluminium conductors.

The structures at the switchyard are of galvanised steel members with bolted joints. The circuit breakers have their own steel frame mounted. The current and potential transformers, line and other isolators are supported by trestles and frames. The bus lightning arrestors are supported on a beam placed across the two rows of columns.

DETAILS OF THE EQUIPMENT

Transformers

These are 7667 kVA, single phase, 50 cycles, $11/\frac{132\text{ kV}}{\sqrt{3}}$ step-up transformers. One bank of three single phase transformers is being used instead of a

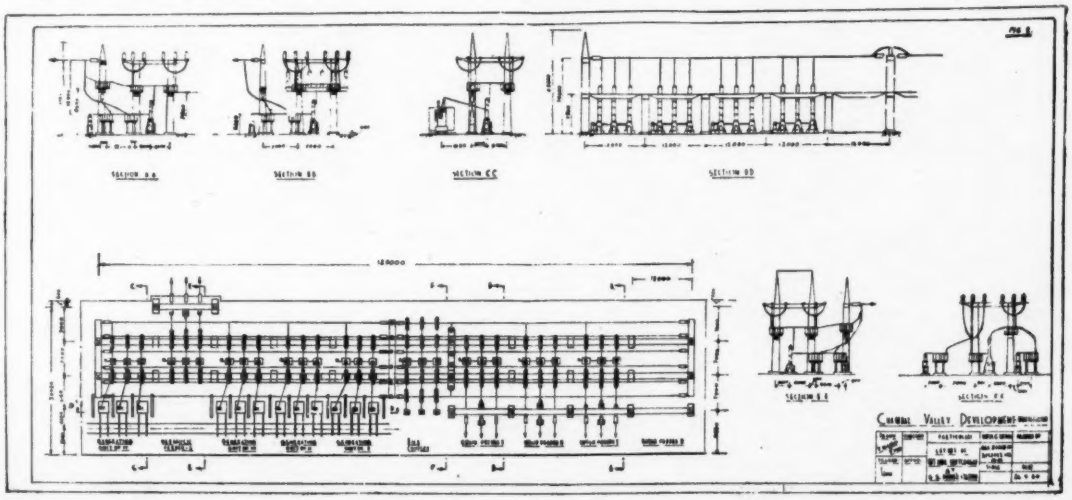

Fig. 1

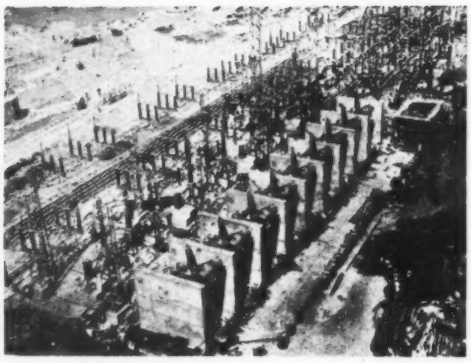

Fig. 2—View of Gandhi Sagar switchyard nearing completion.

3-phase transformer, one single phase transformer being kept as spare for the station. The primaries of these transformers are connected in delta and the secondaries are connected in star, which arrangement provides a third harmonic path on the L.T. side and a neutral point for solid earthing on the H.T. side.

The transformers are of M/s. Mitshubishi Electric Manufacturing Co., Japan. According to their manufacturing practice, all single phase transformers above 5000 kVA and 13.8 kV are made of shell type form-fit construction. Thus the Chambal transformers of 7667 kVA capacity and 11/ $\frac{132\ \text{kV}}{\sqrt{3}}$ rating are also of shell type form-fit construction.

The transformers are forced oil water cooled type, employing an oil pump between the transformers and coolers. The pumps and motors are built, in an integral body housed in a casing made of welded steel plates. In this arrangement there is no danger of oil leakage from bearings and less of floor space is required. These pumps are of 3 h.p. capacity and are installed on the top of the transformers so as to import more oil pressure to the transformers. The tubes of the coolers were originally proposed to be of copper as per the standard design of the company. This was, however, changed to everbrass construction on being pointed out that the water of the Chambal River is considerably hard and our experience showed that scales get deposited in radiators, etc., very easily.

Generally, in order to avoid contamination of transformer oil with moisture in the atmosphere, silica-gel breathers are used. In these transformers nitrogen seal equipment is used for this purpose. As nitrogen is inactive, there is no danger of explosion and it also preserves cooling. The conservator is divided into two parts. In the upper part nitrogen is filled and this is connected to the lower part, which contains oil. Through a system of reducing valves, the pressure of nitrogen supplied to the conservator is reduced to 0.03 - 0.05 kg/cm² from 150 kg/cm² pressure in the nitrogen cylinder.

Circuit Breakers, Current and Potential Transformers

These are of M/s. Galileo and M/s. Asea. All are of the low oil content, spring opening type. The Galileo breakers are of solenoid closing type while the Asea breakers have motor operated spring closing device. The special feature of the Galileo break-

(Continued on page 86)

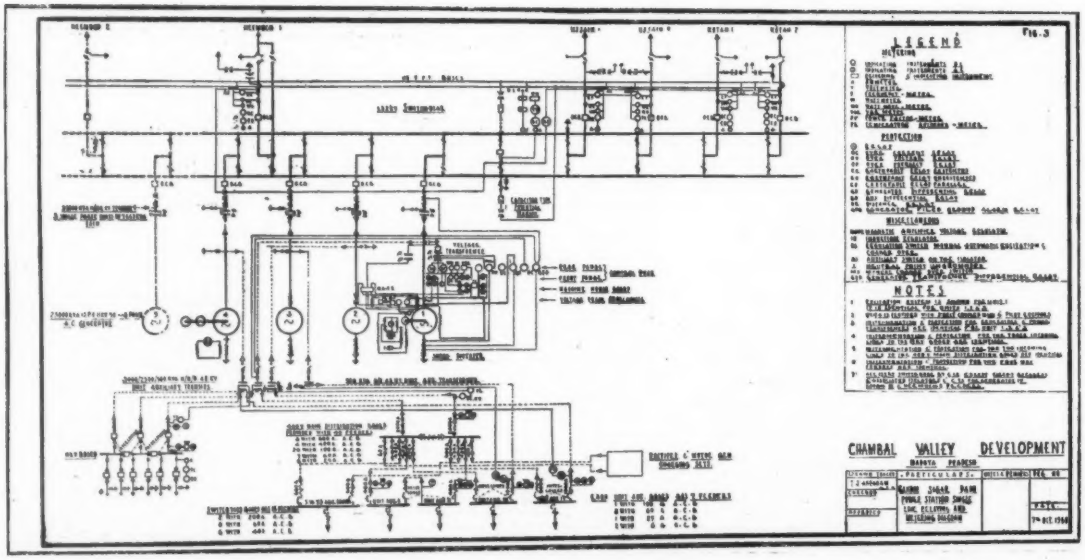

Fig. 3

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SISTA'S-B. 162

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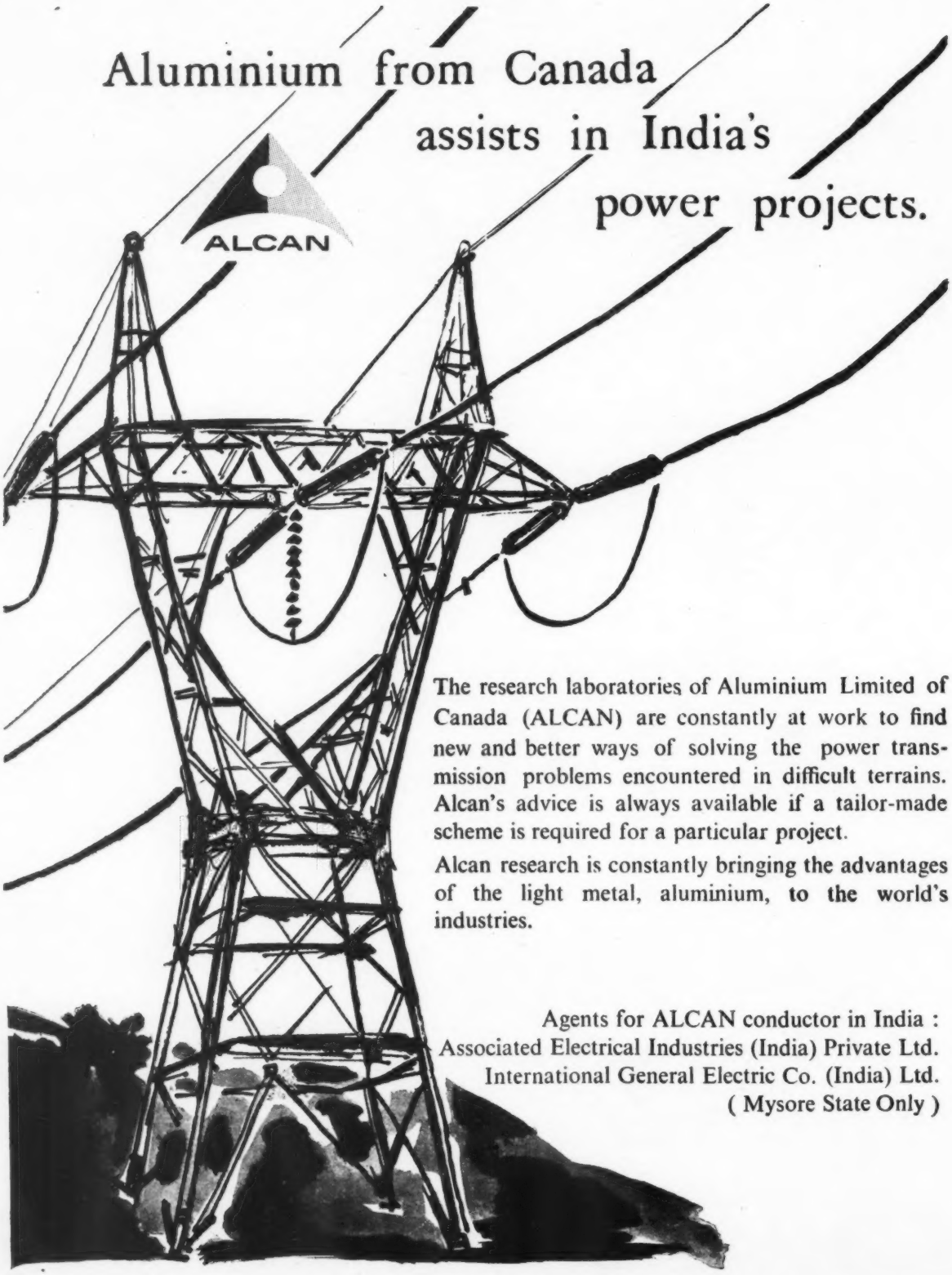

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High Voltage Grid Sub-Stations in Chambal Project (M.P.)

By O. P. UPADHYAY
and R. N. DATTA

POWER from the Gandhi Sagar power station will be fed into the Chambal power grid consisting of 527 miles of 132 kV and 66 kV transmission lines and eight grid sub-stations at Ujjain, Indore, Bhopal, Gwalior, Neemuch, Nagda, Ratlam and Mandsaur in Madhya Pradesh region and 402 miles of 132 kV line and six grid sub-stations at Kotah, Lakheri, Swaimadhopur, Jaipur, Ajmer and Udaipur in Rajasthan region. This article will mainly deal with grid sub-stations in Madhya Pradesh, their design aspects, details of equipment and structures.

The transformer capacity at various sub-stations of the Chambal grid system in Madhya Pradesh and Rajasthan is:

M.P.			
Ujjain	2 Nos.	30/20/10 mVA	132/33/11 kV
Indore	2 Nos.	15/ mVA	66/33 kV
Bhopal	1 No.	7.5/2.5/5 mVA	132/33/11 kV
Gwalior	2 Nos.	7.5/2.5/5 mVA	132/33/11 kV
Neemuch	2 Nos.	10/7.5/2.5 mVA	132/66/11 kV
Nagda	2 Nos.	5 mVA	66/11 kV
Ratlam	2 Nos.	5 mVA	66/11 kV
Mandsaur	1 No.	5 mVA	66/11 kV
Rajasthan			
Kotah	2 Nos.	3 mVA	132/11 kV
Lakheri	2 Nos.	6 mVA	132/33/11 kV
Swaimadhopur	2 Nos.	6/2/4 mVA	132/33/11 kV
Jaipur	2 Nos.	10 mVA	132/11 kV
	2 Nos.	9/6/3 mVA	132/66/ 33 kV
Ajmer	2 Nos.	7.5/3/4.5 mVA	132/33/11 kV
Udaipur	2 Nos.	7.5 mVA	132/11 kV
	2 Nos.	4.0 mVA	132/33 kV

Fig. 1 is a single line relay and metering diagram of the grid sub-station in Madhya Pradesh indicating the switch gear layout, protective and metering equipment at the different sub stations. The major grid sub station at Ujjain, will cater the load requirements in Ujjain district, through the 10mVA windings of the two 30 mVA transformers. The 11 kV feeders will be taken out by Madhya Pradesh Electricity Board for primary distribution. Indore sub-station will cater loads at Dewas, Gambhir, Dhar and Burwaha over 33 kV lines owned by the Madhya Pradesh Electricity Board. Bhopal sub-station will supply M/s. Heavy Electricals and other places such as Itarsi, Sanchi, Nagar, Jahangirabad, and Bhopal city, over 33 kV and 11 kV feeders. Gwalior sub-station will supply Gwalior area, now being served by Gwalior thermal power house. Neemuch and Mandsaur sub-stations will supply loads at Neemuch and Mandsaur towns and adjacent areas in Mandsaur District. Nagda and Ratlam sub-stations will supply the loads in respective areas.

All 132 kV sub-stations have 132 kV single bus system with future provision to interpose bus section isolators for maintenance purposes. The single bus system has the disadvantage of low inaccessibility for maintenance but in view of its simplicity and lower cost, this has been adopted.

Because of overall economy and flexibility, the 66kV side of transformers at Ujjain sub-station is connected to 66kV ring-main bus, the advantages of which are its flexibility for supplying power, even when any of the breakers is under maintenance, and its lower cost in comparison with transfer bus system, although the protection scheme becomes more complicated.

At Indore sub-station, single bus system with bus sectionalising isolator is adopted on 66 kV side. The sectionalising switch is meant to be open normally, as required by considerations of the parallel feeder protection. Due to the large number of 33 kV feeders emanating from this sub-station, transfer bus arrangement on 33kV side is preferred due to its inherent simplicity and ease of physical layout and protection arrangement. The main bus is twice sectionalised and the buses can be connected by a bus coupler breaker.

The 33kV system at Bhopal and Gwalior sub-stations consists of single bus system, which is adopted due to the fewer number of feeders. This system has been preferred due to its lower cost and since these 33kV feeders can tolerate shutdown during maintenance. The disadvantage of this system is that one transformer must take full load of all the feeders during maintenance of one of the 33 kV transformer breakers.

To keep down the cost, no elaborate arrangement has been provided for 66kV bus system at Nagda, Ratlam and Mandsaur where transformers are fed through H.R.C. fuses from the 66 kV bus.

The 11 kV system, at all the sub-stations, is of the single bus system with bus sectionalising switches.

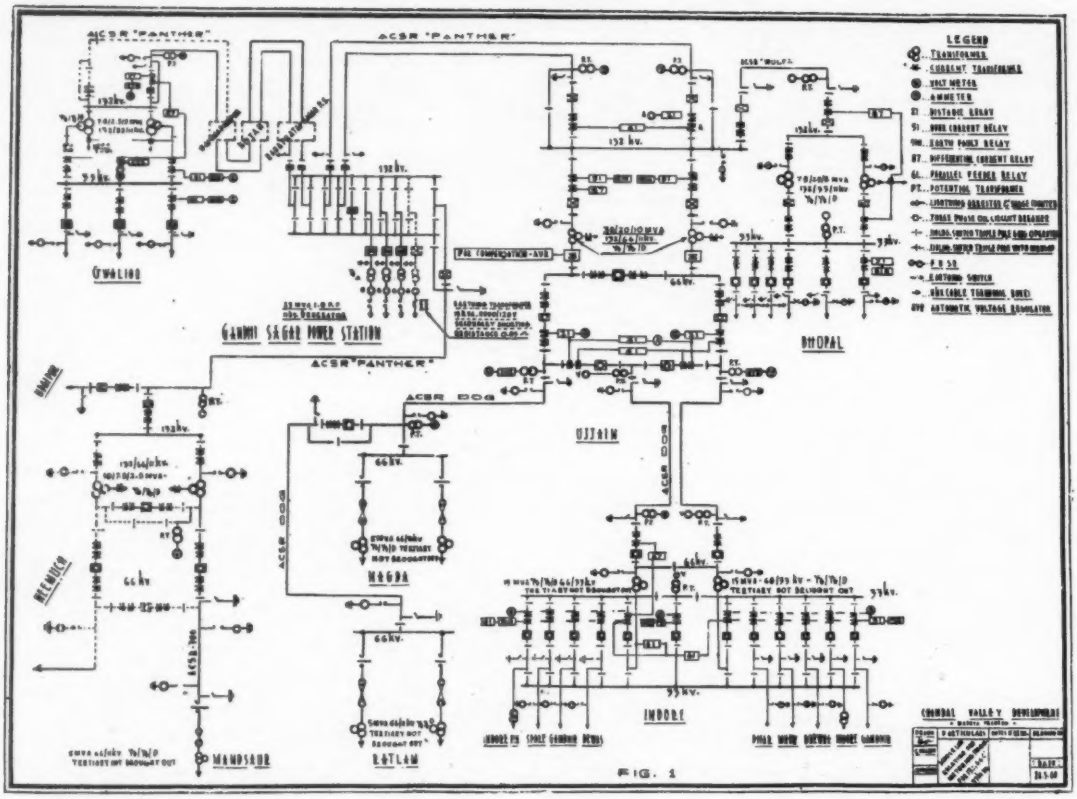


Fig. 1

Since in some sub-stations, the 11 kV windings of transformer are delta connected, necessary arrangement is made for connecting grounding transformer for satisfactory operation of the earth-fault relay, and to provide a grounded system for 11kV primary distribution.

DESIGN FEATURES

The main considerations in the design of the layout of outdoor switchgear are summarised as follows: (1) type of bus system, (2) availability of space, (3) future extensions, (4) directions of incoming and outgoing lines, (5) economy of space and steel structures, (6) electrical clearances, (7) maintenance clearances, and (8) overall appearance from aesthetic point of view.

Due considerations have been given to all these points and a combination of truss type and unit type layout has been adopted. Thus all the 132kV isolators and lightning arrestors are mounted on the ground as in unit type layout and the bus bar bays consist of latticed columns and beams to form a stable and rigid framework to take tensions of the bus conductors as well as the approach span.

The 66kV sections of all sub-stations consist of truss type structures for ease of connections, particularly in complicated ring main bus as at Ujjain sub-station. To economise space requirement, the 66 kV isolators are all mounted vertically on the beams wherever found suitable.

On the 33 kV side of all sub-stations, unit type layout is given preference since with stranded bus conductor and increased number of bays, this type of layout gives a better appearance and it requires much less quantity of steel.

Electrical clearances are maintained as per B.S.S. taking into account the SAG in bus and jumper connections which are of 37/.103" stranded copper conductor. In case of phase to phase distances in oil circuit breakers and transformer bushings, they are retained as per manufacture's standards. The bay widths are adopted on the basis of above clearances and the distances between the equipment centres are adopted on the requirement of maintenance space.

Fig. 2 shows the layout of Ujjain sub-station designed with the above considerations in view. Figs. 3 and 4 show Ujjain and Indore sub-stations during their construction stages.

All the latticed columns and beams required for the sub-stations were designed by the department but

their fabrication had to be given on contract, as the departmental workshop was preoccupied with other important works. All the beams and columns are of welded construction and, for ease of fabrication, the height of columns and length of beams were standardised. The welded construction, although it affords quick fabrication facilities, presents difficulties when it comes to the question of transporting the beams and columns to the various sub-station locations. But this was overcome by use of the departmental 40 ton Diamond 'T' tractor trailor except in case of far away place, where rail transportation was arranged. The supporting structures and frames for O.C.B.'s and current and potential transformers were designed by the department and were fabricated at the departmental workshop itself to save time.

PARTICULARS OF EQUIPMENT AT THE SUB-STATION

Transformers :

All the step-down transformers in the various grid sub-stations are of three winding type. Where two transformation voltages are required as at Ujjain, Bhopal, Neemuch and Gwalior, the secondary and tertiary windings are brought out and where only one transformation voltage is required, the tertiary winding is not brought out as in case of transformers at Indore, Ratlam, Nagda and Mandsaur. The tertiary windings are all delta connected for harmonic suppression. The ratings of transformers are ON/OB with cooling fan controls and radiators. The transformers have graded insulation with the neutrals solidly grounded.

Oil Circuit Breakers :

The particulars of circuit breakers are as below:

	132 kV	66 kV	33 kV	11 kV
Type:	Contraction type	Low oil content outdoor type		Conventional oil circuit breakers indoor type
Symmetrical breaking capacity	2750 mVA	2000 mVA	660 mVA	150 mVA
Time of Interruption at 100% breaking capacity	4.5 – 5 cycles on 50 cps. base	4.5 – 5 cycles on 50 cps. base	5 – 5.5 cycles on 50 cps base	4.35 cycles on 50 cps base

The 11kV breakers are manual operated indoor type

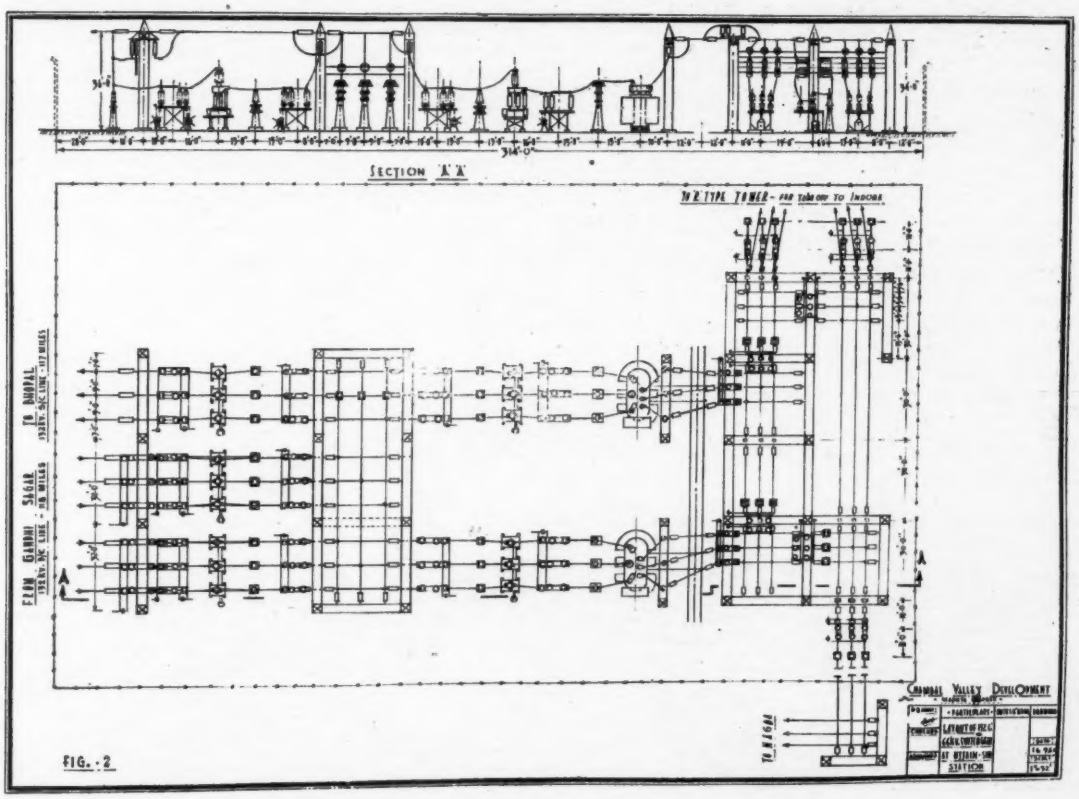


Fig. 2

and form part of the completely enclosed 11kV metal-clad units comprising of bus bars, instrument transformers and relays.

Isolators

The 132 and 66kV isolators are all of single break type suitable for vertical as well as horizontal mounting. They are all manual operated and are fitted with suitable interlock magnet and auxiliary contacts. The 33kV isolators are of manual operated single horizontal break type.

Instrument transformers :

As the 132 kV, 66 kV and 33 kV oil circuit breakers have no arrangement for installing the current transformers within their bushings, all C.T.'s are of separately mounted type. The C.T's are of low oil content type, with double winding in the secondary side and are reconnectable for two ranges on the primary side.

The potential transformers are also of low oil content type with two windings on the secondary side. No fuse or isolator is suggested to be used on the primary side by the manufacturers.

Miniature air break switches with overload release are provided on the secondary side where the P.T. is connected to distance and double line differential protection.

Lightning Arrestors

Lightning arrestors are of ASEA heavy duty, station type and are suitable for use on solidly grounded system. They are of the 10kA class as per AIEE standards and comprise of pre-ionised spark gaps paralleled with grading resistors and in series with valve resistors of highly non-linear characteristics. The maximum discharge capacity of the 132kV arrestors is 150kA, and 100kA for the 66kV and 33 kV ratings. Wherever possible, the lightning arrestors are mounted near the transformer to ensure the absolute protection of the transformers from steep surge fronts.

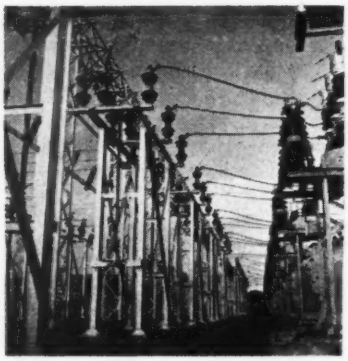


Fig. 4—Indore Substation.

PROTECTIVE ARRANGEMENTS FOR THE TRANSFORMERS

In addition to the differential protection, each transformer is provided with double float Buchholts relay with alarm and trip contacts. The cooling fan circuit is also provided with an alarm system, along with over-temperature and oil level arrangements. At Ujjain and Gwalior sub-stations where the transformers will run in parallel and are also provided with automatic on-load tap changer mechanism, alarm for out-of-step operation of the tap changer is also provided.

In case of transformers at Nagda, Ratlam, and Mandsaur only H.R.C. fuses are used on the primary side.

PROTECTIVE ARRANGEMENTS FOR THE TRANSMISSION LINE

The 132 kV lines are all provided with distance protection. In case of double feeders, parallel feeder pro-

(Continued on page 110)

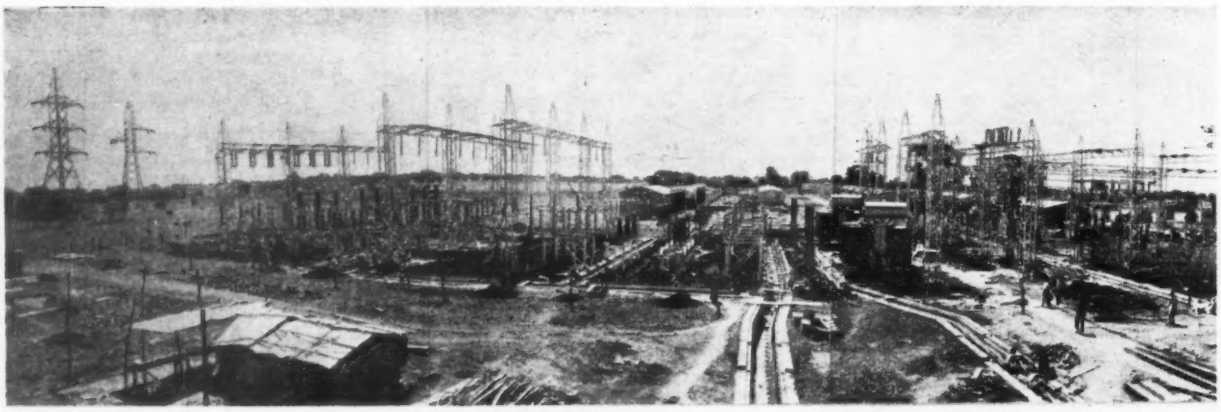


Fig. 3—Ujjain Substation.

Automatic Oil Level Regulation in the Velocity Type Governors Installed at Gandhi Sagar Power Station

By MAN MOHAN RAM

THE three 23 MW turbines are Francis type units and have independent governing units with a common reserve oil pump and tank. The Governor has got an actuator mechanism with velocity control. The speed of the turbine is transmitted by a permanent magnet generator and a synchronous motor to the fly balls of the actuator, which operate the pilot valve by a lever supported on a floating fulcrum. This movement of the floating fulcrum is used for speed or load adjustment and the permanent speed drop. The pilot valve actuates the pilot servomotor which in turn moves the distribution valve by a floating lever fed on the other end by the return mechanism connected to the regulating ring. The complete arrangement is shown schematically in the block diagram (Fig. 1). The actuator mechanism up to the pilot servomotor is a standard equipment patented by M/s. J. M. Voith under Model No. 48.

The typical aspect of the actuator mechanism is the oil dash pot system used for making the governor stable, without any speed drop due to the variation of load and within a negligible amount of time. The dash pot is provided with pre-set and changeable oriffice catridges which dampen the quick movement of the pilot valve as well as the feed back from the regulating ring. Though the cycle of operation is repeated till the equilibrium is established, the movement of the two servomotors is very gradual and steady.

The oil for the governing operation is pressurised and stored in an air-cushioned tank. This ensures an immediate supply for the main servomotors and the actuator mechanism. The pressure generating unit comprises governor oil pump, pilot valve, unloader valve, pressure tank and air draw-off valve and intermediate tank. Two non-return valves are provided as a check between the pump and pressure tank.

Assuming the available pressure in the pressure tank is 20 atm and the oil level in the pressure tank is too high and the shut-off valve is open, the idling cycle operation is as follows:—

Governor oil pump supplies oil from the sump to the unloader valve and non-return valve fitted in this line. With a normal oil pressure of 20 atm, the unloader valve is in the upper position, to which it has been moved by the pressure oil admitted through the pilot valve. With the unloader valve in this position, the pump delivers the oil through the oil cooler to the discharge. Since in the idling cycle the pressure is low, the pressure in the pressure tank closes the non-return valve connected to it so that pressure oil cannot be discharged. With the piston of the unloader valve in the upper end position, the intermediate tank is cut off from pressure tank and is connected to the discharge.

As it has been assumed that the oil level in the pressure tank is too high, the intermediate tank is filled with oil (to the hydrostatic level) and the contents cannot expand. The lines connecting the air valve, whose piston was stepped up, have no more pressure and as a result of the pressure acting on the non-return valve, inside the air valve and in combination with spring action, the piston of the air valve moves down. The non-return valve closes and cuts off the air connection between the intermediate tank and the pressure tank. In the bottom position, the hollow piston of the air valve is lifted from its seat on the non-return valve and as a result, air is admitted through the piston of the air valve into the intermediate tank and the oil in the intermediate tank can now flow by gravity into the oil sump via the unloader valve.

Under the above assumed conditions, the operation of pumping cycle is as follows:—

If the oil pressure in the pressure tank has dropped to about 17.5 atm, the pilot valve becomes effective and the bottom piston compartment of the unloader valve piston is connected to the discharge and the pressure oil causes the piston of the unloader valve to move to the bottom position. As a result, the connection to the discharge line is cut off, and in the line connecting the pump to the pressure tank, a pressure which exceeds that in the pressure tank is set up. Due to this, the non-return valve fitted on the pressure tank opens and the pump starts delivering oil into the pressure tank. At the same time, in the pressure line connecting the unloader valve and the air valve, a pressure which causes the hollow piston of the air valve to be pushed against the seat of the closed non-return valve inside the air valve is set up and at such time the intermediate tank is cut off from the outside air. And also, the lower position of the unloader valve connects the

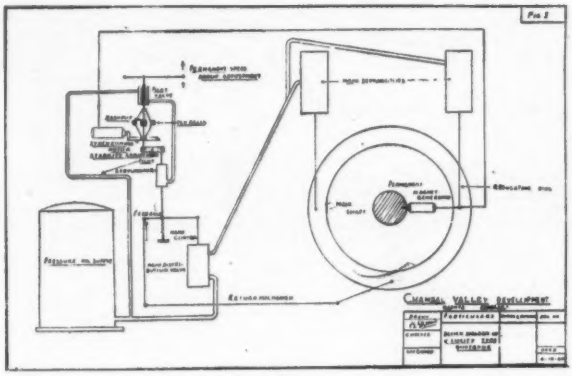


Fig. 1.

pressure tank and the intermediate tank through the air valve, blocking the discharge from the intermediate tank. It can be readily seen that the differential static head between the pressure tank and the intermediate tank (hydrostatic level) maintains an oil flow from the pressure tank into the intermediate tank, while the air trapped inside the intermediate tank is being forced via the air valve into the pressure tank. This cycle slows down, until the oil levels in the pressure tank and in the intermediate tank have been balanced, or in other words, till the oil level in the pressure tank has dropped by an amount equivalent to the volume of air compressed in the intermediate tank.

As soon as the pressure tank has attained its normal pressure, the idling cycle is repeated. In any case, whenever the oil level in the pressure tank is too high, during each pumping cycle air is admitted into the pressure tank, so that the oil level in the pressure tank gradually falls.

Taking the other possibility when the oil level in the pressure tank is too low, or in other words, with the oil levels in the two tanks balanced, and the intermediate tank filled with oil only up to 25%, the operation of the idling cycles is as follows:—

After the pressure in the pressure tank has reached normal, i.e., 20 atm, the governor pump returns the oil to the oil sump via the cooler. As a result, the pressure in the line connecting the unloader valve to the air valve leaks away, and the non-return valve in the air-valve causes the hollow piston to move down. As soon as the disk of the non-return valve comes to rest on its seat, there is no longer any connection between the air cushions in the pressure tank and the intermediate tank. With the unloader valve piston in the extreme upper position, the connection of the oil volumes in the pressure and intermediate tanks has also been cut, and the oil in the intermediate tank is connected to the discharge at such time. The air in the intermediate tank now expands and forces the oil to discharge. At the same time, air is blown off until the air pressure in the intermediate tank reaches the atmospheric pressure.

It should also be mentioned that since there is no pressure in the oil lines connecting the air valve to the change-over valve and the intermediate tank, the piston of the air valve is pushed to the extreme bottom position under spring action, and as a result the intermediate tank also communicates with the atmosphere.

The operation in the pumping cycle is as follows:

If the oil pressure in the pressure tank has dropped, say, to 17.5 atm, the pilot valve becomes effective, and the piston of the unloader valve is caused to move to the bottom position. At such time the pump delivers oil into the pressure tank, which then communicates with the intermediate tank. Since the oil lines connecting the air valve to the unloader valve and the intermediate tank now get energised, the piston of the air valve is forced up and open the non-return valve in the air valve. As a result, the air cushion in pressure tank and intermediate tank again communicate. The air in the intermediate tank is now compressed by the pressure oil coming from the pressure tank. Due to this, the oil level in the intermediate tank will rise above that of the pressure tank. Compressed air passes from the intermediate tank to the pressure tank and because of the gradient, oil flows from the intermediate tank into the pressure tank. Thus, when the oil level in the pressure tank is too low, the direction of the oil flow is reversed and oil level in the pressure tank during the pumping cycle rises by an amount that corresponds to the air volume removed during the idling cycle.

The above mentioned operations are repeated with each operating cycle of the pump. Thus the oil level in the pressure tank will rise automatically to a well defined value. An equilibrium is established when the compressed air cushion in the intermediate tank, on being allowed to 1 atm, fills the intermediate tank.

When the system is in equilibrium, neither air nor oil gets into the pressure tank via the intermediate tank.

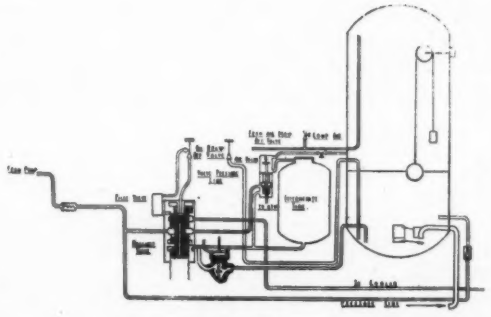


Fig. 2.

(Continued from page 38)

INSTALLATION OF PENSTOCK PIPES AT GANDHI SAGAR DAM

(42 to 50 kg/sq.mm) and yield point of 37,000 p.s.i. (26 kg/sq.mm minimum).

Pressure Hydrostatic Test at 135 p.si. on each of the five penstocks was conducted after installation. The erection of all the five penstocks was completed in about a year's time.

Fig. 3 shows the five completely erected penstock pipes ready for being embedded in concrete.

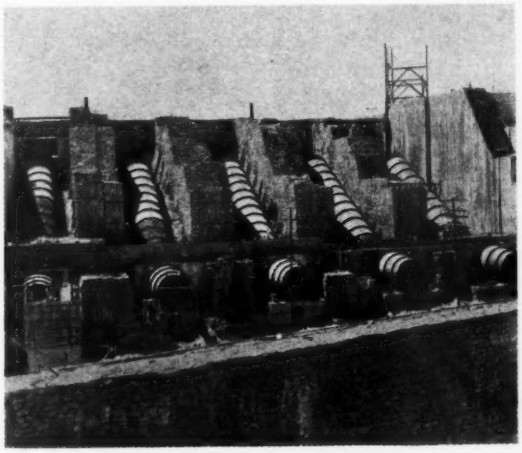


Fig. 3—View of 5 completely erected Penstock pipes ready for being embedded in concrete.

(Continued from page 44)

INSTALLATION OF SLUICE AND CREST GATES IN THE.....

suitable crane was essential. This aspect had earlier been considered and a 90′ boom electrically operated derrick crane, moving on rails, which was surplus with the Bhakra-Nangal Project was purchased. This crane could be used only after heavy overhaul and replacement of electrical gear. The crane had to be provided with a rail track whose gauge was 8000 mm. This much of wide track, which was to be laid on the dam, involved lot of problems. The concreting of the sluice arches in many of the blocks had not been completed and as such, masonry gaps of about 15′ had to be spanned. Further, since the masonry level in all the blocks was uneven, concrete piers were put up to a height of E.L. 1245.00 right along the track at a a distance of about 20′ and were spanned by 33″ × 11″ I section girders, which were readily available at site. These girders were strong enough to take the load of the crane with counter weight of approximately 60 tons and the gate leaf weighing approximately 32 tons.

The erection of the crane, by itself, was an elaborate business. The mast, about 75′ long, had to be guyed from sides for side movement of the boom and from the rear, for movement in the front. There are in all six guy wire ropes, one on either side and four on the rear. These were anchored to concrete blocks which were exclusively put up and tensioned by means of chain pulley blocks and hand winches. The erection was thus successfully completed and the gate leaves were lowered successively in block after block, in a record period of four months. One drawback, in this crane was that the guys had to be removed and put in place for each gate operation, as it moved along the track. The method adopted for operation of the crane was, however, quite satisfactory. Thus, all the nine sluice gate leaves were lowered in their respective chambers and the water was thus stored upto E.L. 1235.00, during that season.

PAINTING

All metal work that would be exposed had been given a shop coat of anti-corrosive bituminous paint. In the field, all the exposed embedded parts and gate leaves were again painted after actual erection and grouting. The surfaces were properly cleaned with wire brushes and rags. Two coats of this paint were generally given except for the parts in contact with flowing water, which were given three coats.

(Continued from page 48)

SPECIAL FEATURES OF THE 23 MW 'SIEMENS' GENERATORS.....

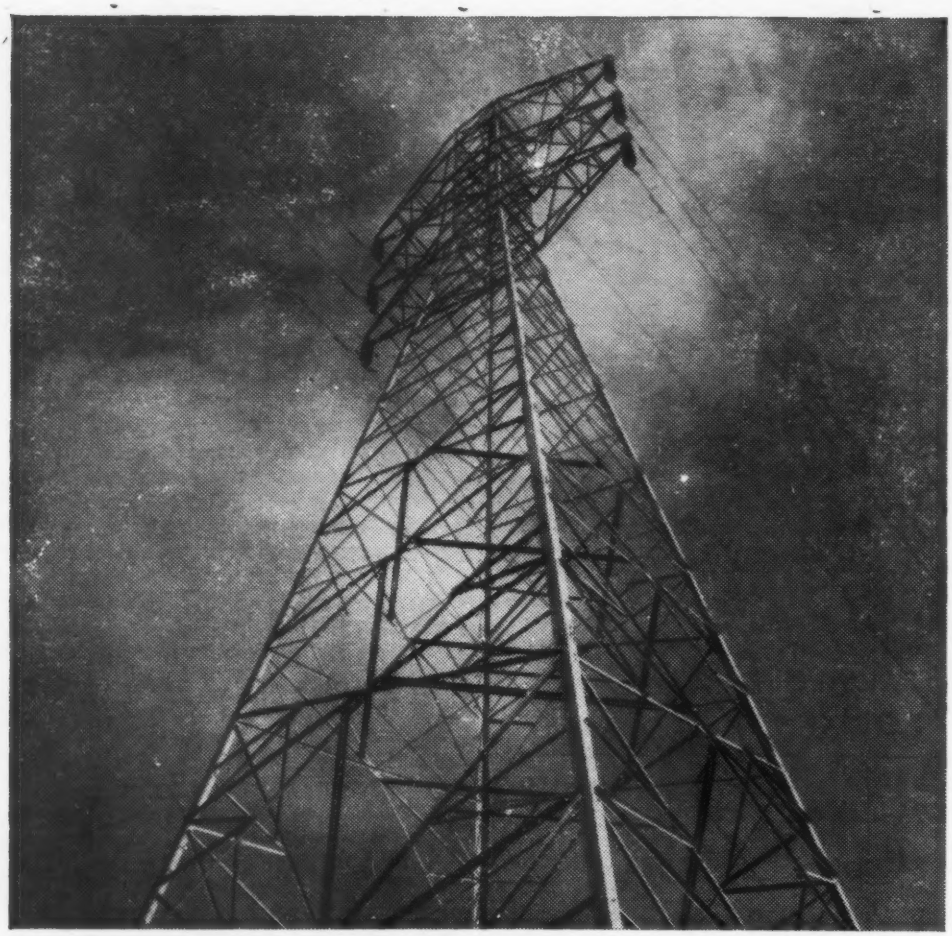
negative excitation output amplifier feeds the negative field winding of the exciter. The feed back elements are used for stabilisation and optimum adjustment of the regulating process. The amount of feed back is proportional to the change of slipring voltage, and acts on a separate control winding of the push-pull pre-amplifier.

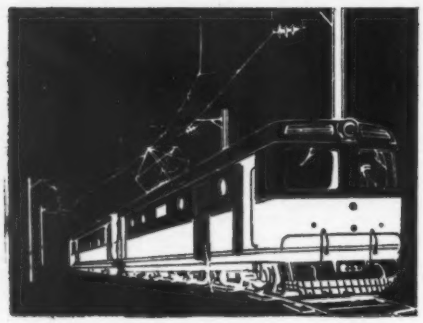
The magnetic amplifier is a very reliable form of voltage regulating apparatus having the following advantages: (1) no moving parts, (2) maintenance free operation, (3) long life, (4) quick response, (5) ease of matching and (6) high overload capacity.

Main details of the magnetic amplifier type of voltage regulator are:

(i) Guaranteed sensitivity	0.5%
(ii) Minimum time taken to respond at given sensitivity	0.1 to 0.2 secs.
(iii) Range of voltage setting	85-110%
(iv) Maximum output with positive excitation	3K.W.
(v) Maximum output with negative excitation	1K.W.

Only a brief technical description of the special features of the generators is given above, since a detailed study of the same is beyond the scope of this article. This would be possible with the data available in the technical pamphlets of Messrs. Siemens Schuckertwerke, Erlangen, extracts from which have been made in the preparation of this article.





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Shilpi-140

Power Transmission from Chambal

By G. V. ANANTHARAMIAH,
and B. K. SHUKLA

THE firm power available from the Chambal Valley Development Scheme, when all the three stages of the scheme are executed, would be 2,15,000 kW at 60 per cent load factor and this is to be shared equally by the two participating States of Rajasthan and Madhya Pradesh. For reaping the full benefits of the scheme, a carefully laid out transmission system is necessary to transmit the power generated at the hydro stations to the distant load centres.

The transmission voltage had to be decided taking into consideration the present and probable future voltage of other lines in the vicinity, and the probability of tying them together at a common voltage later on. In view of the comparatively small blocks of power to be transmitted and the distant locations of the load centres, transmission voltage of 132 kV was found to be the most economical one and was therefore chosen for tying the three power houses as well as for the main radial lines linking up the major receiving stations situated far away; and for the secondary lines, a transmission voltage of 66 kV was chosen. These voltages being among the preferred transmission voltages in this country, any future interlinking with other power systems in the area would also be facilitated.

TRANSMISSION LAYOUT

The layout of the transmission system under the first stage of Chambal Valley development in both Madhya Pradesh and Rajasthan is shown in Fig. 1, and consists of the lines indicated in the Tables I and II.

TABLE 1. *Transmission Lines in Madhya Pradesh*

Sl. No.	Name of line	Route mile	Associated substation capacity	Remarks
1.	Gandhisagar-Ujjain 132 kV double circuit	117	60 mVA at Ujjain	
2.	Ujjain-Bhopal 132 kV single circuit	118	7.5 mVA at Bhopal	Provision for second transformer in the 2nd stage.
3.	Gandhisagar-Neemuch 132 kV single circuit	48	20 mVA at Neemuch	One transformer to be shifted.
4.	Sawaimadhopur-Gwalior 132 kV double circuit	128	15 mVA at Gwalior	Only one circuit to be strung initially-
5.	Ujjain-Indore 66 kV double circuit	32	30 mVA at Indore	
6.	Ujjain-Ratlam, via, Nagda, 66kV single circuit	57	10 mVA, each at Ratlam & Nagda	
7.	Neemuch-Mandsaur 66kV single circuit	28	5 mVA at Mandsaur	

TABLE 2. TRANSMISSION LINES IN RAJASTHAN

1.	Gandhisagar Dam Power House to Sawaimadhopur 132 kV double circuit	117	Kotah 6 mVA Lakheri, 12 mVA, Sawaimadhopur 12 mVA
2.	Sawaimadhopur-Jaipur 132 kV single circuit	87	Jaipur 38 mVA
3.	Kotah-Ajmer 132 kV single circuit.	117	Ajmer 15 mVA
4.	Neemuch-Udaipur 132 kV single circuit	81	Udaipur 23 mVA

SALIENT FEATURES OF THE TRANSMISSION LINES (MADHYA PRADESH PORTION)

Towers: All the 132 kV and 66 kV transmission lines are run on latticed, bolted-type, galvanised steel towers designed for a wind pressure of 15 lbs. per sft., acting on $1\frac{1}{2}$ times the exposed area of one face of the tower and two-thirds the projected area of each conductor.

The details of the types of towers designed and used on the various lines are given in Figs. 2 to 6.

The factors of safety based on crippling strength of struts and elastic limit of tension members in the towers and cross-arms are 2.5 under normal conditions and 1.5 under broken wire conditions. The factors of safety maintained against overturning are also the same as above. One top conductor or earth-wire is assumed broken for tangent towers of double

circuit lines and tangent and angle towers of single circuit lines. For tangent tower, the unbalanced pull due to the broken conductor has been taken as equal to 75 per cent of the maximum working tension of the conductor. For the dead-end towers of single circuit lines, one middle conductor is assumed broken. Three conductors are assumed broken on the same side for angle and dead-end towers of double circuit lines.

The total requirement of steel for the fabrication of towers for the 528 route miles of 132 kV and 66 kV transmission lines in Madhyapradesh, was of the order of about 8,000 tons, just at a time when the country was faced with the acute shortage of steel on the one hand and severe strain on its foreign exchange resources on the other. Under such compelling circumstances, towers for Gandhisagar-Ujjain; Ujjain-Bhopal;Ujjain-Indore and Ujjain-Nagda-Ratlam lines, totalling about 5,000 tons, were ordered on indigenous manufacturers accepting slightly higher rates and delayed deliveries compared to imported towers, purely on preferential policy considerations to encourage indigenous industries.

However, towers for Sawaimadhopur - Gwalior, Gandhisagar-Neemuch and Neemuch-Mandsaur lines, totalling about 3,000 tons only, were imported from Italy.

Fully galvanised towers were preferred to painted towers in order to eliminate the additional maintenance problems the latter would have posed, during the life period of the transmission lines.

The peaks of towers have been so designed as to enable the earthwire to form a protective angle of 30° in the case of all tangent (suspension) towers and 35° in the case of all angle and dead-end (strain) towers.

The conductor to conductor clearances maintained in the tower design are indicated in Figs. 2 to 6 and minimum live-metal clearances provided between live parts and earthed tower on cross-arm members are given in the para below:—

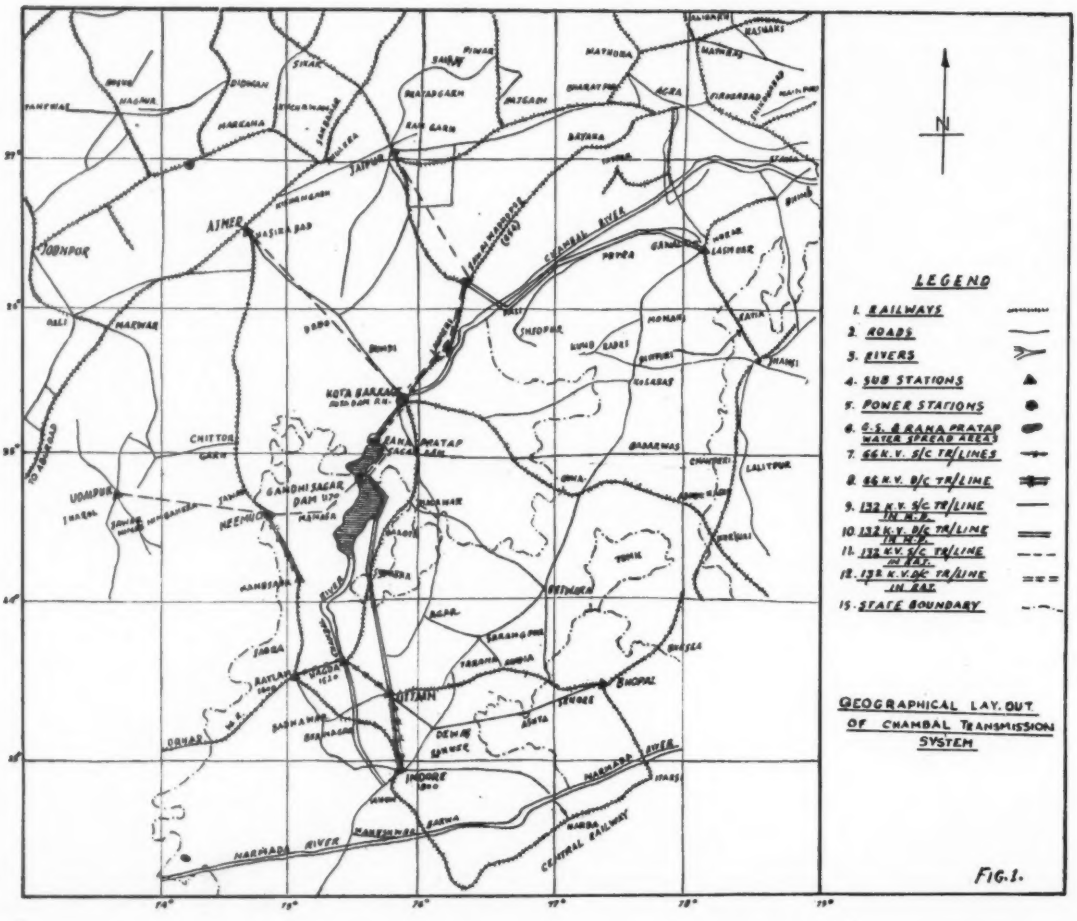
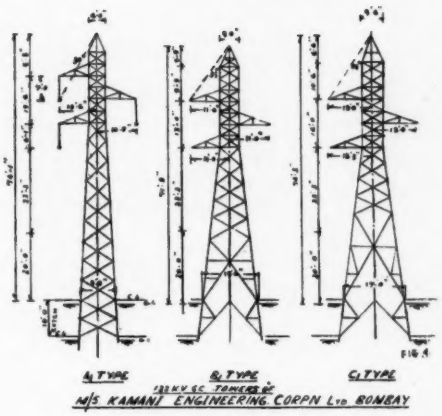
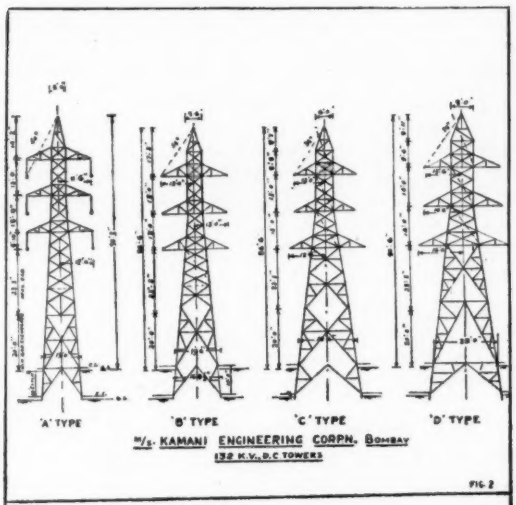


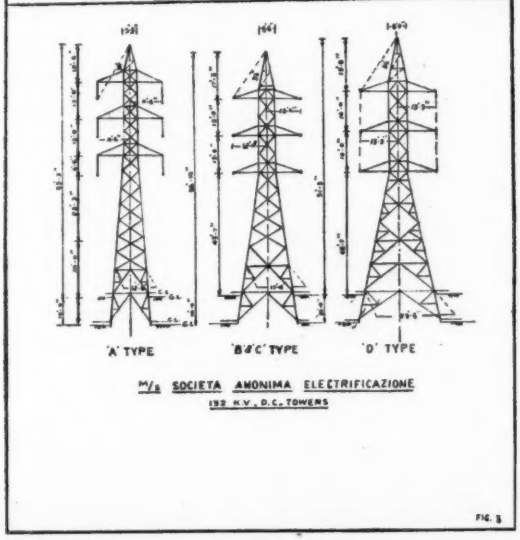
FIG. 1.

	66 kV line	132 kv line
(*a*) Suspension strings in still air and when deflected by wind upto 30° from the normal position of the string.	30″	60″
(*b*) Suspension strings when deflected upto 45° from the normal position in the case of 66 kV lines, and upto 60° in the case of 132 kV lines.	24″	42″
(*c*) Strain strings at strain towers.	30″	60″
(*d*) Jumper strings at strain towers when deflected by wind upto 10°	30″	60″
(*e*) Clearance between bottom conductor and ground.	18′-20′	20 feet

The design of tower foundations is based on an ultimate bearing pressure on soil of 2½ tons per sft., and the factors of safety provided are not less than 2.5 and 1.5 under normal and broken wire conditions. For design of footings it is assumed that the earth weighs 90 lbs. per cft. and that the base of the footings will engage the frustrum of an inverted pyramid whose sides make an angle of 30° with the vertical (i.e., the angle of repose) and the weight of concrete has been taken as 145 lbs. per cft. All the four footings of the towers are similar, irrespective of compression or uplift. Effective bonding between the stubs and concrete is ensured by the provision of angle cleats spaced suitably or a combination of angle cleats and keying rods attached on alternate flanges of the stub angles. The joints between tower stubs and main leg members of the super-structures have been kept at one foot above ground level and are not encased in concrete.







POWER CONDUCTORS

'ACSR' 'Panther' (30/0.118″ Al plus 7/0.118″ st.) corresponding to the standard nominal copper area of 0.2 sq. inch has been used as power conductor on all the 132 kV transmission lines, except the Ujjain-Bhopal line on which ACSR 'Wolf' (30/0.102″ Al plus 7/0.102″ st.) corresponding to the standard nominal copper area of 0.15 sq. inch has been used.

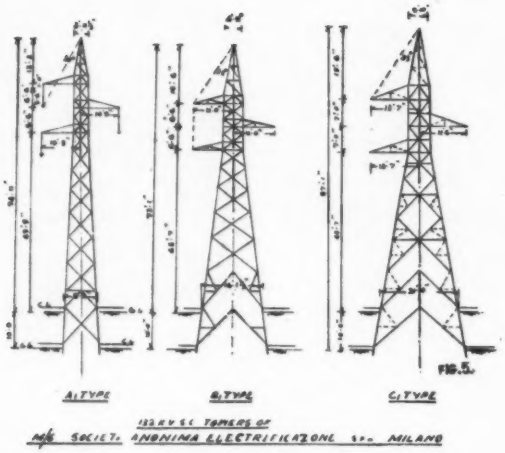
The power conductors used on the 66 kV lines are ACSR 'Dog' (6/0.186″ Al. plus 7/0.062″ st.) corresponding to the standard nominal copper area of 0.1 sq. inch.

GROUND WIRE

One 7/0.160″ galvanised steel earthwire of 70 tons quality on all the 132 kV towers and one 7/0.128″ galvanised steel earthwire of 45 tons quality on all the 66 kV towers, is run over the full length of these lines.

INSULATORS

Brown glazed porcelain insulators imported from Messrs. Nippon Gaishi Kaisha Ltd., Japan, through their Indian Agents Messrs. B. Pannalal and Com-



pany have been used. All insulators are of the Ball & Socket type. Suspension strings are used for angles upto 2° and tension strings for larger angles. Double tension and/or double suspension strings have been used for all railway crossings. Standard discs of size $10'' \times 5\frac{1}{2}''$ have been used for suspension strings of 132 kV lines and for both suspension and tension strings of 66 kV lines. Discs of size $10'' \times 5\frac{3}{4}''$ have been used in tension strings of 132 kV lines.

Nine discs for suspension and 10 discs for tension strings have been used for 132 kV lines whereas five discs for suspension and 6 discs for tension strings have been used for the 66 kV lines. On the approach towers near the substations, over a length of about one mile on either side, the line insulation has been reduced to the extent of one disc relative to the normal string insulation level, for both 132 kV and 66 kV lines, in order to prevent steep wave fronts from reaching the substation equipment. The 66 kV. and 132 kV suspension and tension strings have arcing horns on the line side only.

LIGHTNING PROTECTION

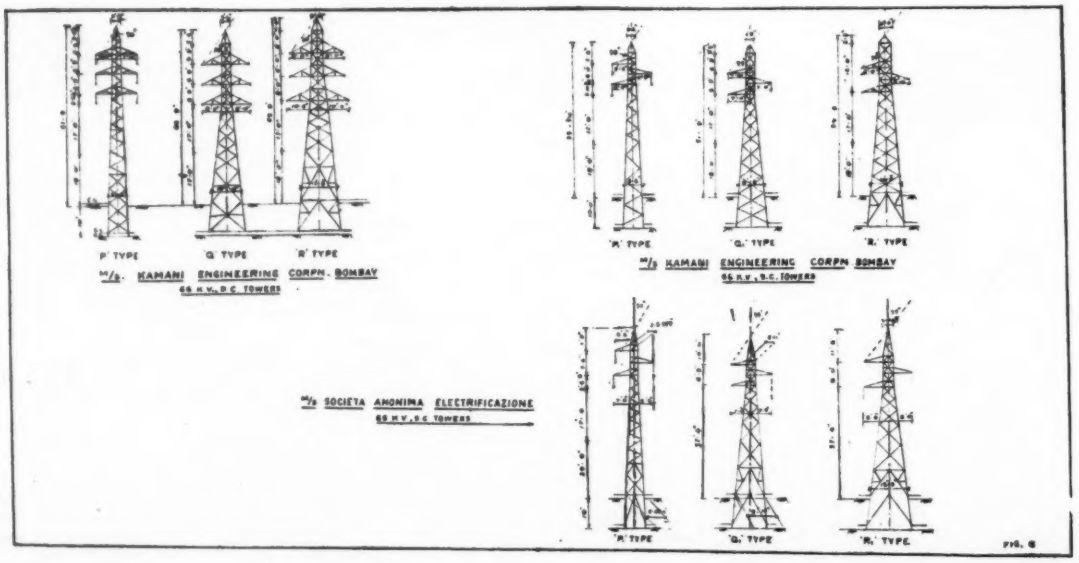
Single groundwire is provided for all the transmission lines so as to give a protective angle of 30° to 35° and to afford adequate protection against lightning.

The impulse strengths of the line insulation provided for the 66 kV and 132 kV lines by using 5 and 9 insulator discs are, 510 and 825 kV respectively. Assuming a maximum lightning surge current of 50, 000 amps. under the severest lightning discharges, the limiting footing resistance works out to 0.02 ohm per kV of impulse strength of line insulation. On this basis the permissible footing resistance work out to 10.2 ohms and 16.5 ohms for the 66 kV and 132 kV lines respectively. Every tower of the 66 kV and 132 kV lines has been earthed by means of 10 foot long perforated galvanised iron pipe buried in the ground and electrically connected to one of the tower legs by 0.1 sq. inch tinned copper tape $1\frac{1}{2}'' \times 3/32''$ thick. The pipe is surrounded with a 6" layer of finely broken coke. The continuous earthwire has been bonded properly to all the towers. The soil resistivity in this area ranges from a minimum of 2,000 ohms to 66,000 ohms per cubic centimeter (representative average figure being less than 7,000 ohms.), as revealed by the tests conducted with an earth-test megger, by the four electrode method.

SAFETY MEASURES

All the towers have been properly grounded as already mentioned above, and enamelled 'Danger'

(Continued on page 68)



Carrier and Radio Communication for the Operation and Maintenance of Chambal Grid System

By Y. NARAYANA RAO

FOR 60 kV and higher voltage lines over ten miles in length, the power line carrier communication system has long been found to be more economical than the conventional type of telephone system established over separate land lines. The advantage of the PLC communication is of a far-reaching nature. This is more so when a vast network of VHF radio communication system, established exclusively for the efficient operation and maintenance of the transmission lines, is interlinked with the PLC communication system. This article gives a short resumé of the combined operation of the PLC and VHF radio communication system adopted in the Chambal Hydro Grid both in Rajasthan and Madhya Pradesh States.

The PLC communication arrangement adopted for the Chambal Grid System is indicated in Fig. 1. Double circuit-to-ground type coupling on all double circuit lines and single line-to-ground type coupling on all single circuit lines has been adopted. The double circuit-to-ground type of coupling affords the facility of either line being taken out of service or even sectionalised, without affecting the carrier channel. It also enables carrying out of the routine maintenance jobs on one of the circuits without affecting communication between the terminal stations. This is secured by earthing the lines at one or both ends, not directly on the coupling capacitor terminals, but on the sub-station side of the wave traps only. Continuance of communication is assured in both types of couplings even in the event of one conductor snapping and falling to the ground, by the antenna effect of the unbroken conductors.

Fixed frequency system (F.F.) is adopted over all sections of the grid system excepting the Gandhi Sagar Dam-Neemuch-Mandsaur-Udaipur and Ujjain-Nagda-Ratlam sections where the wave change over system (W.C.O.) is adopted.

In the fixed frequency system, a set of two frequencies—one for transmitting and another for receiving is required over each line section and by successive amplification, this system ensures that the quality of reception is not impaired even when the communication takes place between stations located far apart.

Whereas, in the wave change over system, only one set of two frequencies is used over a complete section consisting of a maximum of five adjacent stations, by automatic change over of the transmitting and receiving frequencies. The main limitation of the wave change over system is that the intelligence has to travel over the entire section without being amplified anywhere en route and thus the signal to noise ratio at the far end of a wave change over district may be appreciably low. This is a major factor in limiting the maximum number of adjacent sections to five only, over which wave change over system can be effectively adopted. However, the advantages of this system are, the requirement of a single set of two frequencies over the entire district and the requirement of a single carrier set at the intermediate stations interconnecting two or three different carrier directions. Since the inherent principles of frequency change over (or wave change over) with alternate use of the two frequencies make it unsuitable for operations like remote supervision, telemetering and protective relaying which require a continuous channel, this system cannot be adopted where such facilities are required. As such, it is adopted only on radial and relatively less important lines where such facilities are not required. These facilities can, however, be provided, if necessary by the use of additional carrier equipment in conjunction with these wave change over sets.

In comparison with the wave change over system, the only drawback of the fixed frequency system is its requirement of a set of two frequencies for each of the line sections. But this is a disadvantage only in countries where there is a crowding of the frequency spectrum and the frequency allocation is very much restricted. Even in such contingencies, economy in frequency requirements of a system can be effected by judicious allocation of frequencies and repetition of the frequency pairs after ensuring interference free operation. Except for the above limitations, the fixed frequency system scores over the wave change over system by its high quality of reception even at the far end of a carrier district (by repeated amplification at the intermediate stations and high signal-to-noise ratio) and by enabling remote supervision, telemetering and protective relaying facilities to be

provided without the need for major modifications to the existing carrier equipment.

The fixed frequency system has therefore been adopted for the entire double circuit line from Indore at one end to Gwalior at the other end interconnecting the three power stations en route. At present, only telephony is provided on all the lines but when all the three power stations are put into commercial service, load despatching, telemetering, teleprinting and protective relaying facilities are proposed to be provided.

In deciding upon the abovementioned fixed frequency and wave change over districts in the Chambal Grid System, the entire transmission system of Madhya Pradesh and Rajasthan has been treated as a single unit and considerable economy has been achieved without sacrificing operational requirements and efficiency of control. The fixed frequency system over the important and interconnecting circuits and the wave change over system on the relatively less important circuits, thus fully meet with the requirements of the grid system.

Double side band carrier equipment of 10 W maximum capacity has been selected primarily on account of the low initial investment involved. Amplitude modulation in preference to frequency modulation has been adopted on account of its comparative simplicity.

The wave traps used are of the two-wave tuned type, tuned to the frequencies allocated for the particular sections on which they are used. They have been designed to carry a rated current of 400 amps. on the 132 kV lines and 250 amps. on the 66 kV lines. The wave traps are also provided with necessary tuning capacitors and lightning arresters and are rated for an instantaneous symmetrical short circuit current rating of 24,000 amps. on the 132 kV and 15,000 amps. on the 66 kV lines.

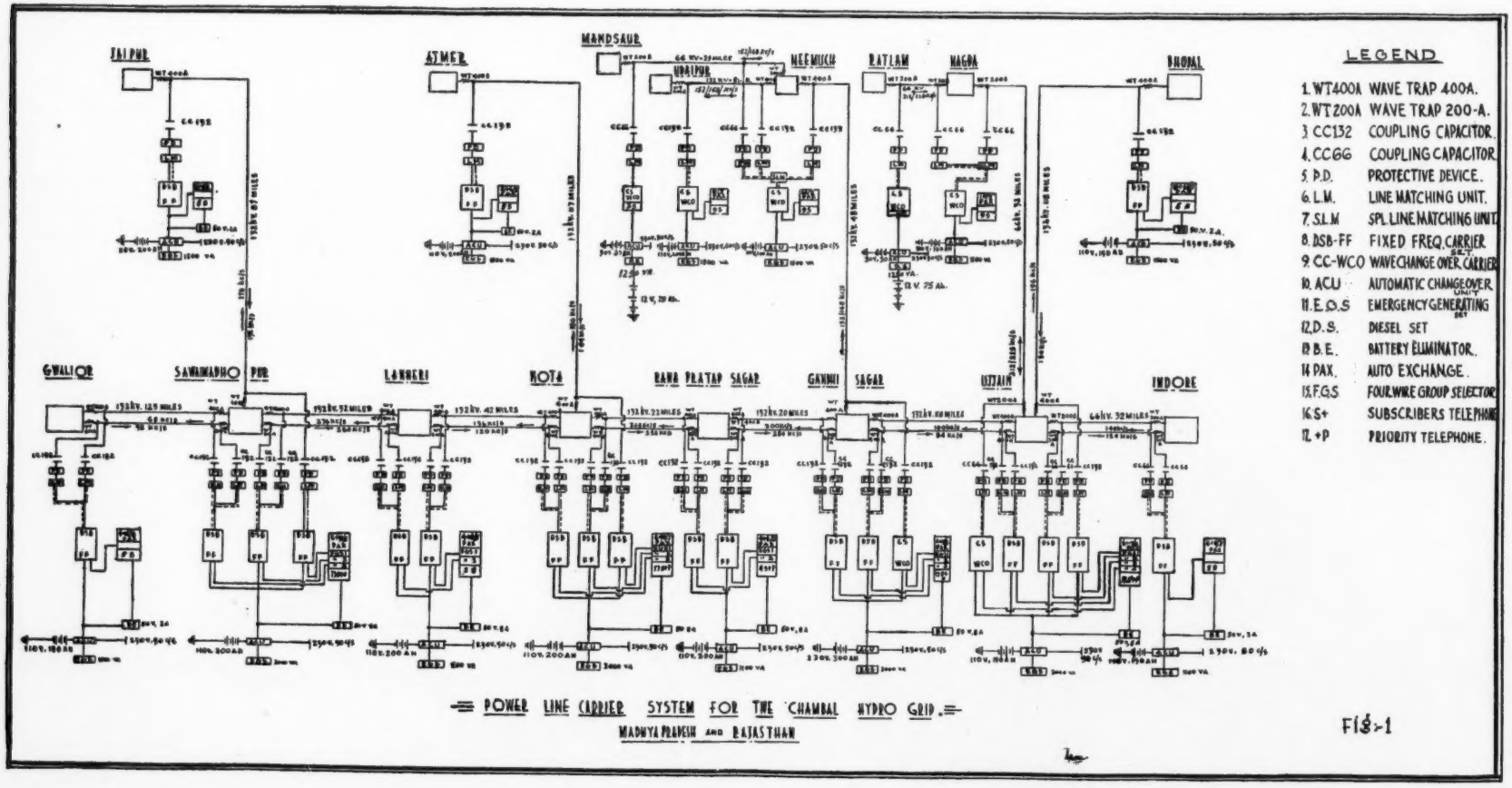
The coupling capacitors used are of the oil filled pedestal type. The outer porcelain insulator units are designed for basic impulse insulation levels of 650 kV and 325 kV respectively for the 132 kV and 66 kV lines and the capacity of these coupling units is 5,576 P.F. and 11,150 P.F. respectively.

Line matching units are used for matching the impedance of the co-axial cable interconnecting the indoor equipment with the outdoor equipment to a wide range of characteristic impedance of the transmission line. Where wave change over type carrier sets are used special type of line matching units which are designed to match the impedances of the two or three different lines to the impedance of the common co-axial cable, have been used. Since these line matching units or tuning units are provided with a drainage coil, adequate isolation from the induced as well as normal high voltages is afforded to the operating personnel. The co-axial cable used for the interconnection of the indoor and outdoor equipment is polythene sheathed and is covered with two layers of aluminium plated iron bands of 0.02 mm thickness. This cable, specially designed for carrier communication purposes, has a characteristic impedance of 125 ohms.

The carrier set is a complete unit by itself with its own transmitter, receiver, amplifier, power supply, etc., each built up in the form of an individual panel. This type of construction aids in the inclusion of additional facilities such as telemetering, teleprinting and other supervisory channels at a later date, without major modifications. Selective dialling system has been adopted with each station having a definite number and definite direction numbers. The carrier sets have got built-in four-wire group selectors which enable interlinking of one carrier communication district with another. These sets are generally mains operated type but at every station automatic changeover facility for operation from D.C. sources is provided. In the event of such a changeover, necessary audible and visual indications are given to the station operator in the control room. The ratings of such emergency generating sets at each of the sub-stations are indicated in Fig. 1. These ratings have been so chosen that in the event of a mains failure the sets will be able to supply all the carrier sets, the VHF set and the telephone exchange in that particular station. Only at sub-stations where the battery capacity is very low, the emergency power supply is obtained by diesel generating sets of 1,250 VA rating which are started off automatically in the event of a mains failure, by a separate set of 12 V, 75 Ah batteries. This is because the cost of the emergency generating sets capable of starting automatically with low battery voltages becomes prohibitive at increased ratings.

Each power station/sub-station in the fixed frequency district is provided with a 10 line or 25 line private automatic exchange for connecting the necessary number of carrier sets and subscribers. Only a limited number of subscribers at each station are provided access to the carrier system whereas communcation among others is possible in the usual manner without access to the carrier system. At the three power stations and important load centres such as Ujjain and Sawaimadhopur, priority facilities are provided so that these can cut into any existing conversation going on between any other sub-stations. Mains operated battery eliminators have been used for power supply to these exchanges.

In the wave change over districts, these exchanges form a part of the carrier set itself (for Nagda, Neemuch and Udaipur sub-stations). Where there is no necessity for a number of telephone sets, as at Ratlam and Mandsaur, only an additional panel is provided which provides a minimum of three telephones at these sub-stations.



POWER LINE CARRIER SYSTEM FOR THE CHAMBAL HYDRO GRID.

MADHYA PRADESH AND RAJASTHAN

FIG-1

With the above equipment, the PLC communication set-up is complete and is operated at the carrier frequencies allocated by the Posts and Telegraphs Department (indicated in Fig. 1).

It was intended to link up the carrier communication system automatically with a network of VHF communication system exclusively set up for the operation and maintenance of the transmission lines. Since this type of completely automatic service proved to be very costly the scheme was suitably modified and the present arrangement indicated in Fig. 2 has been adopted.

Each of the power stations/sub-stations of the carrier system is equipped with a 50 W fixed station type VHF radio equipment. Since the range of the VHF communication is limited to the extent of the line of sight along the contour of the countryside and is also influenced very much by the atmospheric conditions prevailing at any time, the VHF equipment by itself may not always be able to establish a communication link between any two terminal stations. Communication is therefore being established through repeater stations located at appropriate points between terminal stations far apart.

The fixed or terminal stations are of three types—V, Y and Z type. Terminal station type V is equipped with two independent radio links. Terminal station type Y is suitable for use in power stations/sub-stations where only one radio link is required and terminal station type Z is, however, used at stations where no radio link is required.

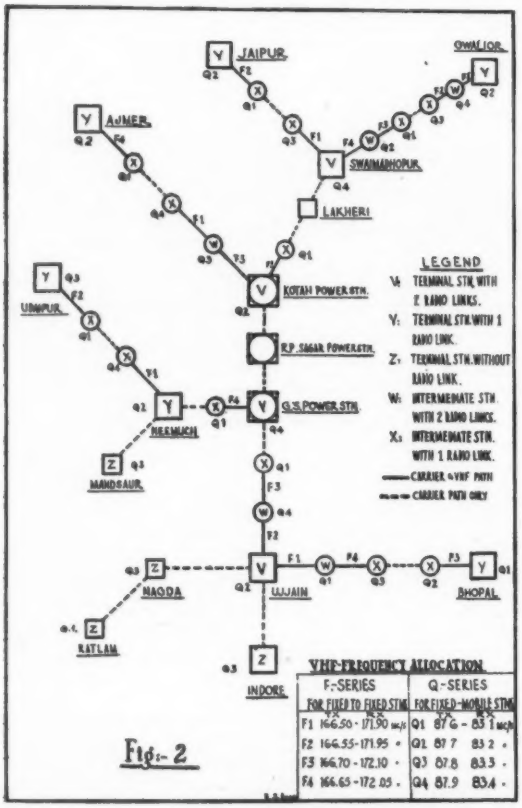


Fig. 2

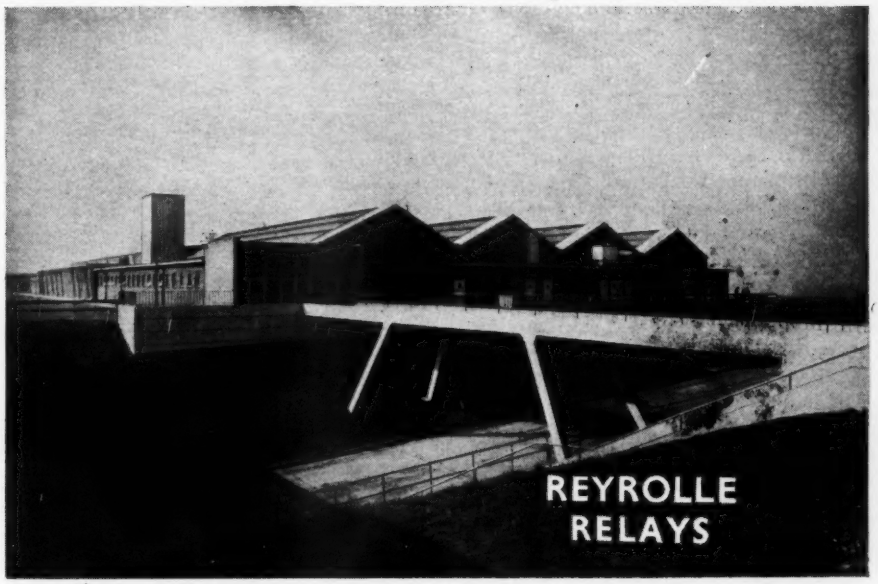
Where the route length exceeds the working range of these terminal sets, the use of intermediate repeater stations becomes inevitable. These intermediate repeater stations rated 20 W, are also of the fixed station type and are of two different types—Type W and X. Type W station has two radio links whereas type X station has only one radio link. The number of these intermediate repeater stations have been provisionally decided as 18 (as shown in Fig. 2) on the basis of a study of the topography of the region and the results of an experimental radio survey. The permanent arrangement and location of these repeater stations will be decided only after the completion of a radio propagation survey now being undertaken by the project. It may even be possible to reduce the number of these repeater stations on the basis of the results of this survey.

Such a combination of fixed and repeater stations, though completing the VHF communication network between the terminal stations, does not form the VHF communication set-up required for efficient operation and maintenance of a transmission system. Mobile VHF sets mounted on jeeps or other vehicles and manpack type sets carried on a person's back (weighing only about 6 kgms) complete the system arrangement. These sets are of 20 W and 750 MW capacities respectively and the function of these sets is to patrol the transmission lines in the normal operating conditions for purposes of routine maintenance jobs and in emergency conditions such as a breakdown, for restoring the power supply at as little loss of time as possible.

The communication between the fixed station and the intermediate repeater station is carried out on the duplex basis, whereas between the mobile unit and the manpack set it is carried out on the two frequency simplex basis.

For fixed-to-fixed station communication directional Yagi aerials are adopted and for fixed to mobile communication omnidirectional dipole aerials are provided. For type W and V stations (with two radio links and one mobile link) four Yagi aerials and two dipole aerials are required whereas the number of Yagi as well as dipole aerials required at the Y and X type stations is two only. For type Z station, since there is only a mobile link, only two dipole aerials are necessary.

At each of these power stations/sub-stations/intermediate repeater stations, the required number of aerials are mounted on a high aerial mast. The decision as to the height of the mast required at each station has to be made after a detailed study of the



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profile of the area, the characteristics of propagation of the VHF waves, the atmospheric conditions, etc., and is tentatively taken as 150 feet. This is however subject to variation on the basis of the results of the radio propagation survey.

For establishing communication from the manpack sets to the mobile set and therefrom on to the nearest terminal station over the radio link, a separate VHF frequency scheme is necessary. Four sets of link frequencies (F-series) and four sets of mobile frequencies (Q-series) indicated in Fig. 2, have been adopted and approved by the Adviser, Wireless Planning and Co-ordination.

The fixed station equipment in the VHF communication system is of the mains operated type whereas power supply to the equipment in the intermediate repeater stations is provided by installation of a coupling capacitor potential device of 1,000 VA capacity, installed directly on the main transmission line itself. Adequate capacity voltage regulators are installed in order to provide a constant voltage supply to the repeater sets.

The mobile unit and the manpack set are, however, battery operated. The mobile unit is fed from a separate 12V battery in the vehicle, whereas the manpack set is supplied from a 3-volt silver zinc battery within the set. Suitable battery charging arrangements have therefore been provided for the 13 mobile and 50 manpack sets that are in use over this transmission system.

In the event of mains failure at the terminal station, the emergency set provided for ensuring emergency power supply to the carrier set also serves the VHF set by the automatic change over arrangement described earlier. At the intermediate repeater stations, the power supply under such conditions is obtained by a diesel generating set of 1,250 W capacity which is automatically started by means of the 12 volts, 75 Ah capacity battery provided therein and which is kept in continuous charge by a mains connected rectifier unit.

As already mentioned, the VHF communication in any region depends chiefly upon the topography of the region. Where the country is plain the operating range of the equipment is much more than where the country is undulated and hilly. The number of repeater stations and their location could be few and far between in the earlier case whereas in the latter case, more number of repeater stations located close to one another becomes essential.

The PLC *cum* VHF radio communication network of the Chambal Grid System described in this article is a very modern communication system incorporating facilities for reliable and quick communication within this region. Such a combined system helps very much in the efficient operation and maintenance of the Grid System, in normal as well as in emergency conditions to ensure a dependable power supply at all times. The importance of this modern communication system will be appreciated more when all the three power stations of the Chambal Grid System have been commissioned into service and load despatching, telemetering and teleprinting and carrier protection facilities are also provided.

(Continued from page 62)

POWER TRANSMISSION FROM CHAMBAL

boards have been provided on all towers in the vicinity of villages, railway and road crossings.

Anti-climbing device, consisting of barbed wire looped around tower legs to a height of ten feet, is also provided on all towers.

OTHER FITTINGS

Step-bolts have been provided on one leg of every tower, and number plates giving the location number are mounted on each tower. Galvanised steel serrated bird guards have been provided above the suspension insulators on the cross-arms of all tangent towers.

Stock bridge dampers consisting of resiliently supported weights equipped with a suitable clamp for attaching them to the conductor have been installed at all strain locations in order to damp out resonant vibrations in power conductors. One damper has been used per conductor for spans upto 1,200 feet and two for spans longer than that. Tapered armour rods have been installed as reinforcement at all suspension points to protect the aluminium strands of conductors from possible fatigue failure due to resonant vibrations. They are also intended to provide protection against flash-over burns.

At all the railway and telecommunication line crossings, no guarding arrangements have been made as per recommendations contained in the extant code of practice governing such crossings and the same have been approved by the concerning departments. All cases of parallelism with the existing telecommunication lines along the roads and railways have been approved by the Power and Telecommunication Coordination Committee and the Posts and Telegraphs department have provided adequate protective remedial measures on their lines, wherever necessary, at the cost of the project.

Role of Materials Testing Laboratory in Construction of Gandhi Sagar Dam

By A. VENKATESWARA RAO

AT the investigation stage of major river valley projects, thorough exploration and intense scientific study regarding the suitability of the construction materials available in the vicinity of the project have to be taken up. To ensure efficiency and maximum economy, so that the selection of materials below standard may not endanger the safety of the structure, and rejection of materials without proper study, taking into account the modern technological advancement, may not result in wasteful expenditure, the investigations for correct assessment of the properties of the materials is very essential.

MASONRY

Till recently, many of the dams in peninsular India were constructed with stone masonry in lime-surkhi mortar. Most of these dams are meant for a single purpose, irrigation, unlike the present multipurpose river valley projects. The latter projects involve complicated designs and more capital outlay. In view of anticipation of the quick returns out of the projects and fast economical advancement aimed at after political independence, the construction period of these projects should be relatively short. Therefore the conventional materials for construction will be inadequate. At the same time, concreting involving heavy construction machinery, skilled technical personnel and specialists may also be not advisable in every case for a country like ours facing the problem of unemployment of unskilled labour and shortage of skilled personnel and specialists, besides difficulties of foreign exchange for the purchase of the construction plants and spare parts in time. Moreover, the concrete costs nearly 25 to 30 per cent more than stone masonry for comparable strengths and other properties.

In view of the above, for Gandhi Sagar Dam, stone masonry in red cement mortar is used as the main construction material for hearting with cement concrete facing for the most vulnerable locations having constant or intermittent flow of water. The latter is meant to be durable and weather resistant. In the dam where there are intricate structures with complicated stresses heavy reinforcement is used.

Stone

Being the major construction material occupying a solid volume of more than 50 per cent of the masonry, the characteristics of the stone play an important part on the strength and serviceability of the masonry structures. Hardness, compressibility, specific gravity, absorption, durability and soundness are a few of the important characteristics in additon to the crushing strength, generally considered before final selection.

The physical characteristics of the quartzite and quartzitic sandstones used in the construction of Gandhi Sagar Dam are given in Table I.

TABLE 1.

Type of rock	Specific gravity.	Unit weight.	Absorption percentage (24 hrs.)	Crushing strength.	Remarks.
White quartzite	2.66	166 lbs./-cft. or 2.66 kg./dm³	0.50 by weight.	6.4T/□″ or 1007 kg/cm²	This rock is available in the river bed and in quarries 3 to 5 miles upstream of the dam.
Quartzitic sand stone	2.58	161 lb./-cft. or 2.58 kg/dm³	1.32 by weight.	3.15/T/□″ or 496kg/-cm²	This rock is available on the left flank and is used for non-spillway portion on this flank.

It is thus seen that the stones more than satisfy the specification requirements irrespective of the source it is obtained from. The cube crushing strength of the stones used for dam construction when tested by applying load on its natural bed, is as high as 14,000 to 15,000 P.S.I. (984 to 1055 kg/cm²). This gives an extra factor of safety nearly five times over and above that of the crushing strength of mortars used; and this may not be too much because of the various contingencies that arise while testing of the stones on the one hand and using them in actual construction on the other.

Sand

It is well-known that the fine aggregates in mortar or concrete mixes, which constitute by absolute volume nearly 25 per cent of the masonry, reduce the amount of binding agent. As cement is compara-

tively costly, reduction in cement content due to the use of fine aggregates, in addition to economy, minimises shrinkage and cracking.

Investigations were conducted to explore natural sand deposits as it is the most common fine aggregate used for construction works. As the river flows in hilly region with rocky bed, natural sand is not available in the required quantities within a reasonable distance. As such, two rod mills of 30 tons per hour capacity were procured under the aegis of the Technical Co-operation Mission and installed at site to supplement the sand from natural deposits. The geological process by which a deposit was formed or by which it was subsequently modified are responsible for many of the characteristics that may influence decision as to its utilisation. Physical characteristics and chemical composition of the particles in the deposit, overburden and ground water level mostly influenced the selection. Fortunately river Chambal has very little flow in non-monsoon period and also overburden on natural deposits is not much. As such sand deposited during rainy season could easily be quarried, collected over the right flank and transported. Sand available in the nearby nallahs was also quarried and used. This natural sand is mostly derived from sedimentary formation and has high percentage of carbonates. Properties of a representative sand sample are given in Table II.

TABLE 2. Properties of Chambal River Sand.

Specific gravity	2.73
Absorption (24 Hrs.)	0.79%
Materials passing through I.S.S. No. 8	0.49%
Organic impurities: Less than the maximum specified in the Standards.	
Tensile strength of 1 : 3 mortar	
3 days	412 P.S.I. or 29 kg/cm²
7 days	517 P.S.I. or 36.3 kg/cm²
Compressive strength of 1 : 3 mortar	
7 days	2417 P.S.I. or 170 kg/cm²
Total water soluble solids	0.02%
Loss on ignition.	26.4%
Total carbonates expressed as $CaCo_3$	64.4%
Fineness modulus (for coarse variety)	3.40

The percentage of loss in sodium sulphate soundness test is excessive in finer fractions. Sand samples giving tensile strengths of less than 60% compared with the standard sand were rejected. In majority of the quarries sand was very coarse and not well graded. Fine and medium varieties available in small quantities were therefore used for blending with natural coarse sand.

PUZZOLONA

Use of puzzolonas in lime mortar is in vogue from the Roman period. Apart from economy, the use of puzzolona, where it is available within a reasonable distance or can be manufactured at a reasonable cost, in mortar or concrete mixes imparts very good qualities like improvement in workability, reduction in thermal shrinkage, leaching, bleeding reduction in heat generated, higher resistance to chemical agents and permeability. Disadvantages of slow rate of development of strengths, longer periods of curing, lower unit weight and slight increase in unit water content are of not much significance in major construction works since they are seldom subjected to full load within 3 months after completion, by which period the puzzolonic cements develop almost the same or even slightly more strengths than neat Portland cement mixes.

No puzzolona was readily available in the vicinity of Gandhi Sagar Dam and as such investigations were taken up to select suitable soil for manufacture of surkhi, the common variety of puzzolona used in many parts of India. Soil selected satisfied the following standards: 1. Clay content not less than 20 per cent. 2. Soluble salts not more than 0.3 per cent. 3. Kankar nodules or precipitated calcium carbonates 3 per cent maximum.

Brick balls of 3″ to 4″ diameter prepared from the selected soils are calcined, pulverised and screened to the required degree of fineness. Electrically operated disintegrators fixed with sieves having 80 meshes to an inch were used. The well-burnt brick powder satisfied the following standards:

Particles passing through I.S.S. No. 15 not less than 65 per cent.

Particles passing through I.S.S. No. 60 not less than 96.5 per cent.

Specific gravity	2.82
Unit weight	85 to 88 lbs/cft.
SiO_2	40 to 80 per cent.
Al_2O^3 Fe_2O_3	10 to 35 per cent.
MgO	not more than 3 per cent.

CEMENT AND WATER

The cost of ordinary Portland cement works out to more than 40 per cent of the cost of the masonry. The strength of mixes vary as high as 50 per cent due to variations in the quality of the cements. The wide variations in the characteristics of cements produced from different factories and even the variations in the same brand from a factory influence greatly the control over the variations in strengths. Samples of Portland cement from the factories situated at Sawai-Madhopur and Lakheri were tested in Alipore test house. Results indicated that the cements satisfied the Indian Standards and were selected for use in construction works. Water from river bed was tested and found suitable for construction and curing purposes.

LABORATORY INVESTIGATIONS DURING CONSTRUCTION STAGES

Productivity, employment of minimum resources and quality are the three aims to be secured in construction stages. In spite of thorough investigations in preliminary stages, it is not uncommon to experience difficulties to procure materials, continuously, meeting the specification requirements and of uniform quality. Many a time the quality of materials obtained changes considerably during the period of construction, and many problems have to be faced for proper utilisation of available materials to improve the quality and serviceability of the product and to effect economy. To investigate the specific construction problems in detail and to introduce most recent technological advancement after careful study and tests, laboratory investigations are essential.

Important laboratory investigations at G. S. Dam

1. *Determination of optimum percentage of surkhi for red cement*: Results indicated that for the same type of surkhi available at G. S. Dam the optimum percentage varies with the fineness of surkhi. The optimum percentage is found to be 19 per cent by weight of cement for surkhi as obtained from the surkhi mills (F.M.O. 55 to 0.60) and 15 per cent for surkhi passing through I.S.S. 15.

2. *Effect of fineness of surkhi on the strength of mortars*: Results indicated that finer surkhi developed higher strengths at earlier ages and 20 per cent of replacement of unscreened and screened (I.S.S. No. 15) surkhis developed nearly comparable strengths at the age of 3 months.

3. *Utility of surkhi towards fine aggregates*: Natural coarse sands are replaced by surkhi (F.M. 1.2 to 1.7) to an extent 3 per cent by weight of sand. Results indicated considerable improvement in workability, plasticity and impermeability of mortars .

4. *Washing of silt and clay from natural coarse sands—Effect on strength of mortars*: In natural coarse sands the percentage of particles passing through I.S.S. No. 8 are less than 1 per cent. Experiments conducted on mortars with washed and unwashed sands indicated the mortars with unwashed sand developed almost same strengths as those of the mortars with washed sand indicating thereby that there is no effect of washing on the strength of mortars. The workability of mortars, however, is improved. On the basis of these experiments, cumbersome process of washing of sands was avoided resulting in a good deal of economy. Results are shown in Table III.

5. *Blending of fine with natural coarse sand*: As two varieties of natural sands, one coarse (F.M. 3.67) and the other finer (F.M. 2.12) but both not satisfying the specification requirements for grading, were available, experiments conducted on blending of fine with coarse sands indicated an increase of 2 per cent in unit weight of sand and 6 to 25 per cent increase in strength of mortars when optimum percentages are used. (Fig. 3).

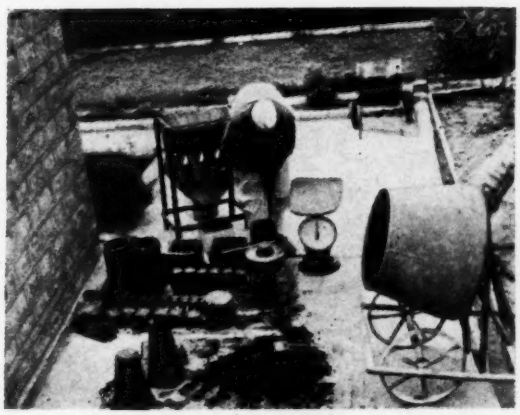
TABLE 3.

Strength of mortars with unwashed and washed coarse sands

Type of cement	Strength of cylindrical test specimens at the age of 28 days.				Remarks
	1:2.75 mortar		1:4 mortar		
	Unwashed sand	Washed sand	Unwashed sand	Washed sand	
1	2	3	4	5	6
Neat cement	2575 PSI or 181 kg/cm²	2648 PSI or 186 kg/cm²	1010 PSI or 71 kg/cm²	1152 PSI or 81 kg/cm²	Natural coarse sand having F. M. nearly 3.10 is used in the experiments.
Red cement (80% Portland cement plus 20% surkhi)	1957 PSI or 137.6 kg/cm²	1905 PSI or 141 kg/cm²	873 PSI or 61.3 kg/cm²	752 PSI or 52.9 kg/cm²	Local surkhi is used. Proportioning of cement to sand is on volumetric basis.

6. *Utility of rock powder—a by-product at aggregate screening plant*: Investigations for determining the utility of this by-product indicated that this can be advantageously used to the maximum extent of 15 per cent with natural coarse sands to improve the grading of the sands, strength, uniformity and cohesiveness of plastic mortars. This bye-product, otherwise considered waste, was thus used advantageously. (Fig. 4).

7. *Workability agents:* Investigations on the surface wetting agent 'Lissapol' N indicated its use in mass concrete mixes improve the workability and allows reduction of 6 to 8 per cent in unit water content for the same consistency.



Casting of test pieces.

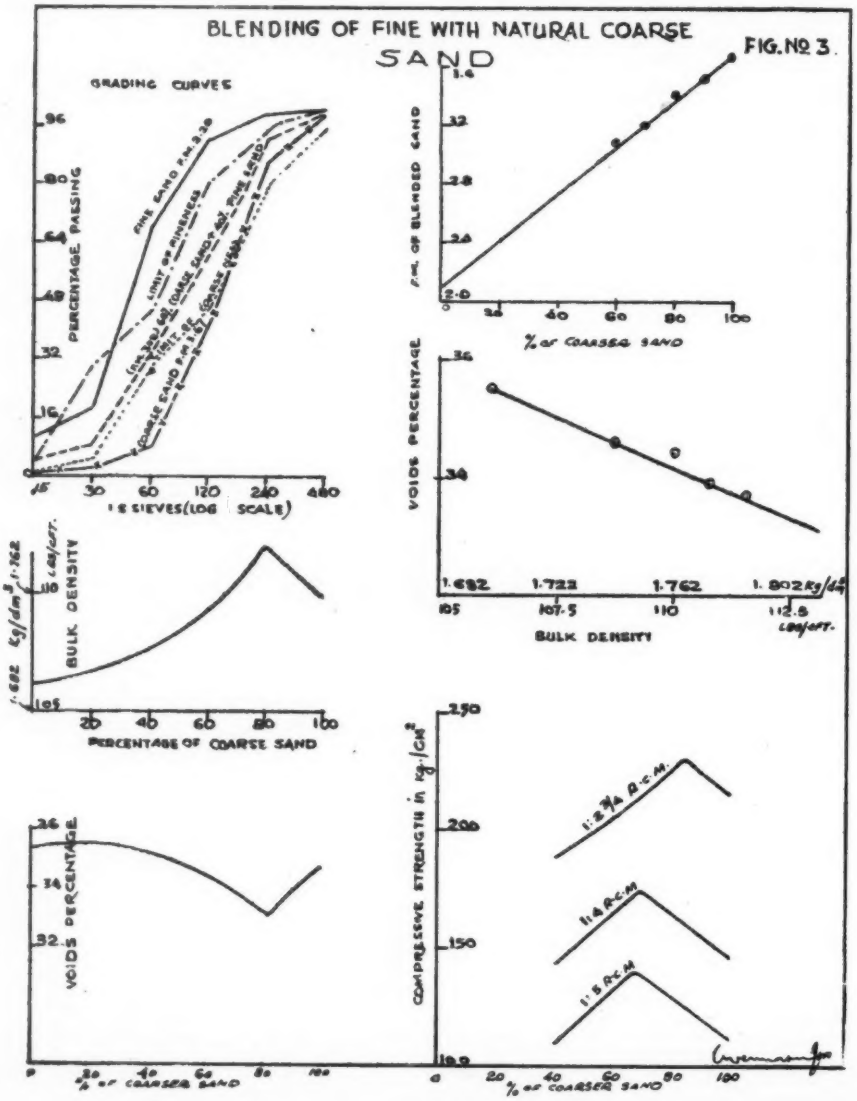
8. *Delay in consumption of mortars—Effect on strength and workability:* Difficulties were experienced to consume the mortars within 30 minutes after mixing as prescribed earlier. Experiments indicated that the red cement sand mortars when, covered with wet gunny bags can be used without much loss of workability up to 1½ hours after mixing. (Fig. 5).

Various other investigations on bulkage of sands, utilisation of finer variety of natural sands, crushed sands, the effect of oversize, undersize fractions of aggregates and gap grading of coarse aggregates on the properties of concrete mixes, fineness of surkhi and its effect on permeability of mortars, rate of development of heat and red cement concrete mixes, etc., were conducted and the results obtained were incorporated to the best advantage in construction works.

DESIGN OF CONCRETE MIXES

Superiority of rational proportioning of mixes, aiming at the most economical and best utilisation of available materials to produce concrete mixes capable of developing the required qualities in plastic condition and after hardening, over arbitrarily chosen concrete mixes without taking into consideration the effect of maximum size, grading of aggregates, water requirements and water cement ratio of the resulting mixes, hardly needs any emphasis.

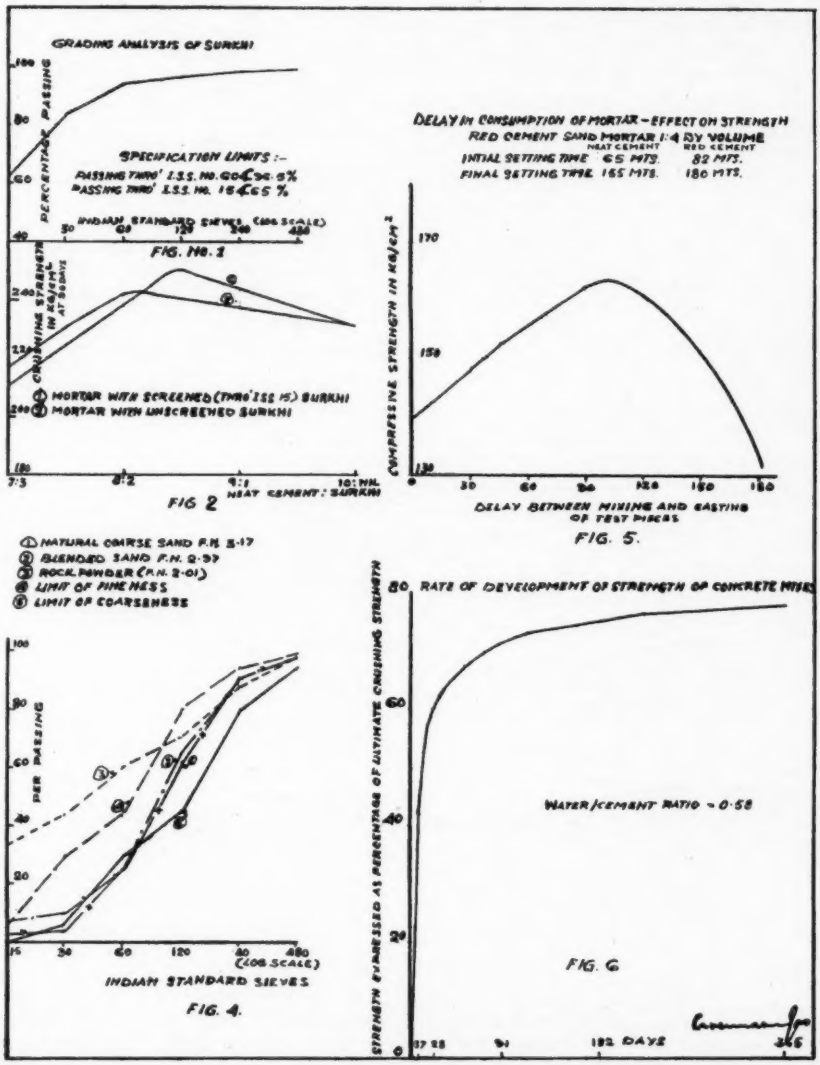
For design of concrete mixes, standard practice



specified by U.S. Bureau of Reclamation was adopted. For "Good" degree of control, coefficient of variation of 15 per cent was taken. In order that 80 per cent of the tests fall above the specified design strength, the concrete mix was designed for an average strength of 1.15 times the minimum specified strength.

The concrete mixes for the top of 3′ of spillway bucket, rear blanket, spillway crest, piers, sluice sides, penstocks, draft tubes, 3′ on waterface of divide wall and guide walls were designed for a water cement ratio of 0.52 and the design of mixes for other location was governed by the strength requirements.

The mixes were designed for the maximum specified slump in order that the consistency of concrete at the time of placement would be greater than the minimum specified slump. Whenever high frequency vibrators were used on the job, the slumps were reduced to 2/3 of that specified. The optimum percentage of aggregates were determined through extensive laboratory tests conducted on the aggregates proposed for the work. The various sizes of coarse aggregates were proportioned to produce maximum dry density and the proportion of the fine aggregates to coarse aggregates was determined to give the best workability keeping the unit water content constant. Then the concrete mixes were designed on the assumption that when all the ingredients are mixed and compacted thoroughly the mass attains a volume which is the sum total of actual volume of individual aggregates, cement, puzzolona, water, entrained air and any other admixture if used. After the trial mix was computed theoretically, slump, after mixing the


GRADING ANALYSIS OF SURKHI
PERCENTAGE PASSING
SPECIFICATION LIMITS :-
INDIAN STANDARD SIEVES (LOG SCALE)
FIG. No. 1
CRUSHING STRENGTH IN KG/CM² AT 90 DAYS
MORTAR WITH SCREENED (THRO' ISS IS) SURKHI
MORTAR WITH UNSCREENED SURKHI
HEAT CEMENT : SURKHI
FIG 2
DELAY IN CONSUMPTION OF MORTAR – EFFECT ON STRENGTH
RED CEMENT SAND MORTAR 1:4 BY VOLUME
HEAT CEMENT
RED CEMENT
INITIAL SETTING TIME 65 MTS. 82 MTS.
FINAL SETTING TIME 155 MTS. 180 MTS.
COMPRESSIVE STRENGTH IN KG/CM²
DELAY BETWEEN MIXING AND CASTING OF TEST PIECES
FIG. 5.
① NATURAL COARSE SAND F.M. 5·17
② BLENDED SAND F.M. 2·97
③ ROCK POWDER (F.M. 2·01)
④ LIMIT OF FINENESS
⑤ LIMIT OF COARSENESS
PER PASSING
INDIAN STANDARD SIEVES
FIG. 4.
RATE OF DEVELOPMENT OF STRENGTH OF CONCRETE MIXES
STRENGTH EXPRESSED AS PERCENTAGE OF ULTIMATE CRUSHING STRENGTH
WATER/CEMENT RATIO = 0·58
182 DAYS
FIG. 6

calculated ingredients, was observed in the laboratory. If the desired slump was not obtained, the actual amount of water required was found and the adjustments necessary were made in the trial mix based on the principle for constant slumps—total mix parts are directly proportional to the water-cement ratio. Optimum proportions of the ingredients for various concrete mixes, characteristics of plastic and hardened concrete mixes used actually at site are given in Tables IV and V.

Airentrainment

Recent research in concrete technology has proved beyond any doubt the distinct advantages of purposeful airentrainment and the entrained air formed almost a fifth ingredient in the concrete mixes used for major river valley projects.

Airentrainment is done even in mortars for stone masonry works but its use in mortars is not so generalised as in the concrete mixes. Unlike entrapped air that exists in the concrete mixes in the form of lumps, investigations in various laboratories and experience in field has demonstrated clearly the improvement in the qualities of plastic and hardened concrete by entraining 3 to 6 per cent of air in the form of small spheroids of diameter 0.003 to 0.05 inch. Advantages of airentrainment are improvement in workability, durability, plasticity, cohesiveness, impermeability, reduction in linear expansion, unit water and sand contents. It off-sets the disadvantages due to the use of manufactured and not well-graded aggregates to a certain extent. The quantity of the airentraining agent (AEA) to be added, depends on the percentage of air to be entrained which in turn depends on the maximum size, nature, grading of the aggregates, type and fineness of puzzolona used. Airentrainment below 3 per cent may not improve the workability and durability to the required degree and more than 6 per cent reduces the strength of the mixes considerably without contributing appreciably to the improvement of workability and durability. Investigations were conducted in this laboratory on indigenous and foreign products of AEA and Vinsol resin NVX was finally selected. Results of laboratory investigations at Gandhi Sagar Dam showed:

1. For the same consistency and concrete materials 3.2 per cent of reduction in unit water content can be affected for each per cent of airentrained with additional advantage of some improvement in workability.
2. Reduction in ultimate compressive strength of airentrained concrete is 175 to 180 P.S.I. for each per cent of entrained air for the same water cement ratio in airentrained and non-air entrained concrete mixes.
3. With crushed aggregates and natural sands; a reduction of $\frac{3}{4}$ to 1 per cent in sand content can be effected in concrete mixes for each per cent of air entrained.
4. The quantity of airentraining agent required to introduce the same per cent of air in red cement concrete mixes is nearly double that required for neat cement concrete mixes.
5. Reduction in unit weight of concrete is directly proportional to the quantity of air present in the concrete mixes. This reduces the unit weight of materials required per unit volume of concrete which makes the airentrained concrete economical.
6. To maintain constant slump and equal strength with and without airentrainment in concrete mixes 10 to 15 pounds of extra cement per cubic yard of concrete is required in airentrained concrete.

Workability Agents

For mass concrete mixes in some of the major construction works, surface wetting agents like 'Lissapol' N were used to improve the workability. Investigations were conducted on 'Lissapol' N and the same was used in the mass concrete below the top 3′ in spillway bucket.

Experiments were also conducted for selection of the best materials for construction such as sand for cement pointing of stone masonry faces, bricks for power house building, water proofing agents, etc.

Quality Control

With the rise in tempo of concreting works, which were carried out departmentally, the responsibility of control over the quality of materials, all concreting operations, and other departmental works, control over manufacture of mortars, pressure grouting operations, etc. was entrusted to the laboratory organisation. To exercise control over production of concrete at batching plant, a field laboratory, with necessary equipment and charts was established near the plant. One more field laboratory was established at site to exercise control over manufacture of mortars and to exercise control over materials including manufacture of crushed sands by rod mills. A check was exercised over the construction of masonry.

Routine testing

The primary purpose of the field laboratory is routine testing of concrete, mortars and their ingredients and to maintain a complete record of the materials, mortars used and concrete placed in every part of the dam and the appurtenant works.

A doubt about the useful purpose of testing of the hardened concrete or mortars long after use in the structures was very much in the minds of many engineers. Apparently it may look futile to test the

TABLE 4. Concrete Construction Data—Non Airentrained Concrete

Class of Mix.	Clean separation of aggregates-percentage of total:					Mix composition-pounds per cyd					W C+P by weight	Average slump in inches	Slump in inches (specified)	Unit wt. in lbs/cft.	Crushing strength in P.S.I. Age in Days.						Remarks
	-3/16″	3/16″ to ¾″	¾″ to 1½″	1½″ > 3″		Water	(C) Cement	(P) Surkhi	Sand	Coarse aggregates					3	7	28	91	182	365	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A_2 (2500-3″ PSI.)	32.0	21.34	16.3	24.4	6.96	255	300	75	1070	2330	0.68	2.27	2 to 3	149.9	926	1676	2523	2871	2980	3138	
A_3 (2500-1½″)	35.3	29.3	25.2	10.2	—	293	350	88	1160	2125	0.67	2.50	3 to 5	147.9	—	1550	2496	2797	—	—	—
B_1 (3000-3″)	31.5	20.8	16.7	25.0	6.0	260	370	92	1070	2250	0.55 ±0.03	2.35	1½ to 4	149.6	1128	1969	3068	3393	3510	3684	—
B_2 (3000-1½″)	35.9	28.3	24.6	11.2	—	285	420	105	1140	2040	0.55 ±0.33	2.39	2 to 4	147.7	1240	1909	3009	3460	3621	3802	—
B_3 (3000 PSI.—¾″)	41.5	55.25	3.25	—	—	330	590 to 600	—	1270	1730	0.55	3.1	2 to 4	145.3	1703	2482	3330	4050	4333	4547	—

TABLE 5. Red Cement Sand Mortars: Volume Batching. Cement : Surkhi—4 : 1 by weight.

Proportion of red cement mortar.	Mixed composition per bag of cement				Crushing strength in kg/cm² Age in days.						Tensile strength in kg/cm² Age in days.			Remarks.
	Cement	Surkhi	Sand	Water	3	7	28	91	182	365	3	7	28	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1: 2.75	1.0 bag	0.3 cft.	4-1/8 cft.	6 gl.	84.3	123.7	186.2	233.0	260.5	270	11.7	16.6	25.1	Average unit weight of mortar 141.5 lbs/-cft. or 2.27 kg/cm³.
1: 4	1.0 bag	0.3 cft.	6 cft.	8 to 8½ gallons	54.6	84.3	149.1	181	214	220	9.2	11.7	18.3	Specification limits at the age of 28 days cube crushing 50 T/□′ strength. minimum.
1: 5	1.0 bag	0.3 cft.	7½ cft.	10 gl.	34.5	64.2	117.2	149	175.5	188	5.4	8.0	14.4	Tensile strength: minimum 10 T□′ minimum

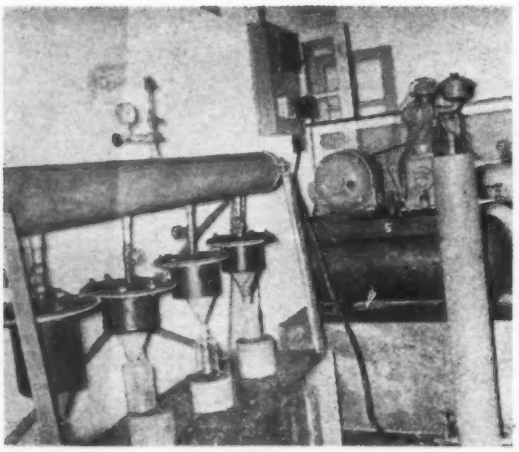
representative samples of mortar or concrete over which nearly another 20 feet high masonry or concrete is laid. Should the specimens fail to meet the specification requirements of strength and other characteristics, is the entire masonry with that mix and that overlying it, going to be demolished? Obviously this is neither practicable nor advisable. Under such circumstances the question is: what is the exact purpose behind testing of hardened mortar or concrete test pieces.

The following paras may perhaps answer the above doubt to a certain extent.

1. The concrete or mortar is a product manufactured with rigid control over quality. Field tests are only a practical means of judging the relative quality and to maintain uniformity. Hence if the test pieces fail to meet the strength requirements, additional curing should be ordered as long as necessary to develop the desired quality strength of other characteristics on such portions of the structure as are represented by the specimens.

2. The time to be left after concreting to strip the formwork is based on the development of the strength of concrete mixes. Normally for removal of formwork, the concrete placed in that structure should be tested for strength and on the basis of the strengths obtained the removal of formwork should be based.

3. If the permeability results indicate the mortar or concrete pervious beyond the specified limits, that portion of masonry or concrete can be drilled and grouted till that portion satisfies the specification requirements. Results of permeability tests conducted in laboratory will be useful to compare with the results of permeability tests conducted on masonry at site by drilling. Poorer results than those obtained in the laboratory indicates the defect in workmanship, and the comparison will be useful for improving the quality.



Permeability apparatus manufactured by the project.

4. From economic considerations, the average strength of the concrete mixes should be as close to the minimum specified as can be achieved at site. Low coefficient for variation assumed than that can be achieved may endanger the safety of structure and high coefficient will result in wastage of cement. Excessive variations in quality always entails the danger of inferior concrete being placed in important locations of the structure and lower coefficient of variation indicate uniform control. This can be achieved only by constant control and evaluation of test data by statistical methods and is possible only by testing the concrete specimens at regular intervals.

5. The strength of the standard test pieces not only indicates the strength of the structure but also reflects on other properties such as materials used, durability, water-tightness, and ability to resist abrasion. From the weight of the test pieces, unit weight of hardened concrete can be computed which is useful in design of gravity dams.

6. To a large extent the test results permit the determination of the safe load allowable on the structure and the useful life or serviceability of a particular structure.

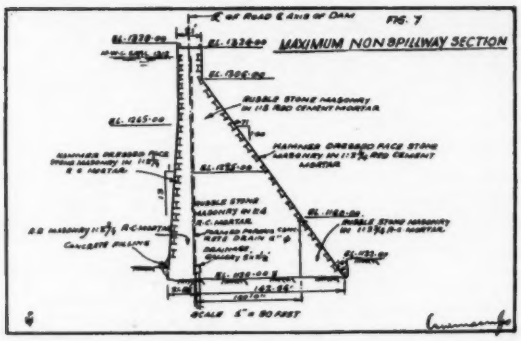
7. Tensile strengths of mortars indicate the durability of the structure to a certain extent.

8. The test results help to establish uniform standards and drawl of specifications and serve as guidance in future works for improving the quality.

MORTAR MIX PROPORTIONS

Like in many other dams, for construction of Gandhi Sagar Dam, the proportions for red cement sand mortars are specified as 1:2¾, 1:4 and 1:5 by volume. These proportions of cement and sand are fixed rather arbitrarily without taking into consideration the nature, grading, unit weight and other qualities of sand, unit water content, workability desired and water cement ratio of the resulting mix while fixing the cement fine aggregate ratio. Rational mix design on similar principles adopted for concrete mixes and fixing the proportions to attain the specified strength, durability and impermeability taking into consideration the available materials should be adopted. With the arbitrary proportioning of mortars, especially with volume batching, the strengths vary to a great extent and possibility of the use of weaker mortars on the job cannot be ruled out, unless unnecessary rich mortars are adopted. The masonry in large dams is not subjected to its full forces till a few years after completion. In view of this it may be advisable to take into consideration one year strengths of mortars for design especially in lower portions.

Various routine tests to assess the physical properties of construction materials, concrete and mortar mixes in plastic and hardened conditions and to exercise uniform control over the production and placing operations are carried out in the main and



field laboratories. Occasional tests were conducted on cement, surkhi and stones to assess if their characteristics satisfy the specification requirements. Experiments were conducted as per standard procedures prescribed by ISI and ASTM. Results of various concrete and mortar mixes are given in tables.

RECORDS

Permanent records clearly and accurately maintained will be of abundance help for reference at a later stage, to work out details such as safe allowable loads on structure, to settle contracts, to evolve test data and preparation of reports, development of specifications, and for reference by other projects.

Laboratory reports keep the higher officers informed regularly the test results as to the effectiveness of control over production of concrete or mortars, placing and other operations of concrete or mortars, investigations conducted and contribution made towards the technological development.

With this end in view, comprehensive, neat and accurate records regarding all the tests conducted, data of all materials and the products used, information regarding all the operations of concreting were maintained in the laboratory. In addition to the above a record of the meteorological observation and river water temperatures which are useful to the engineers if or the design and other purposes was also maintained.

STATISTICAL ANALYSIS OF THE TEST RESULTS

The test results were analysed by the statistical methods to assess the degree of control exercised

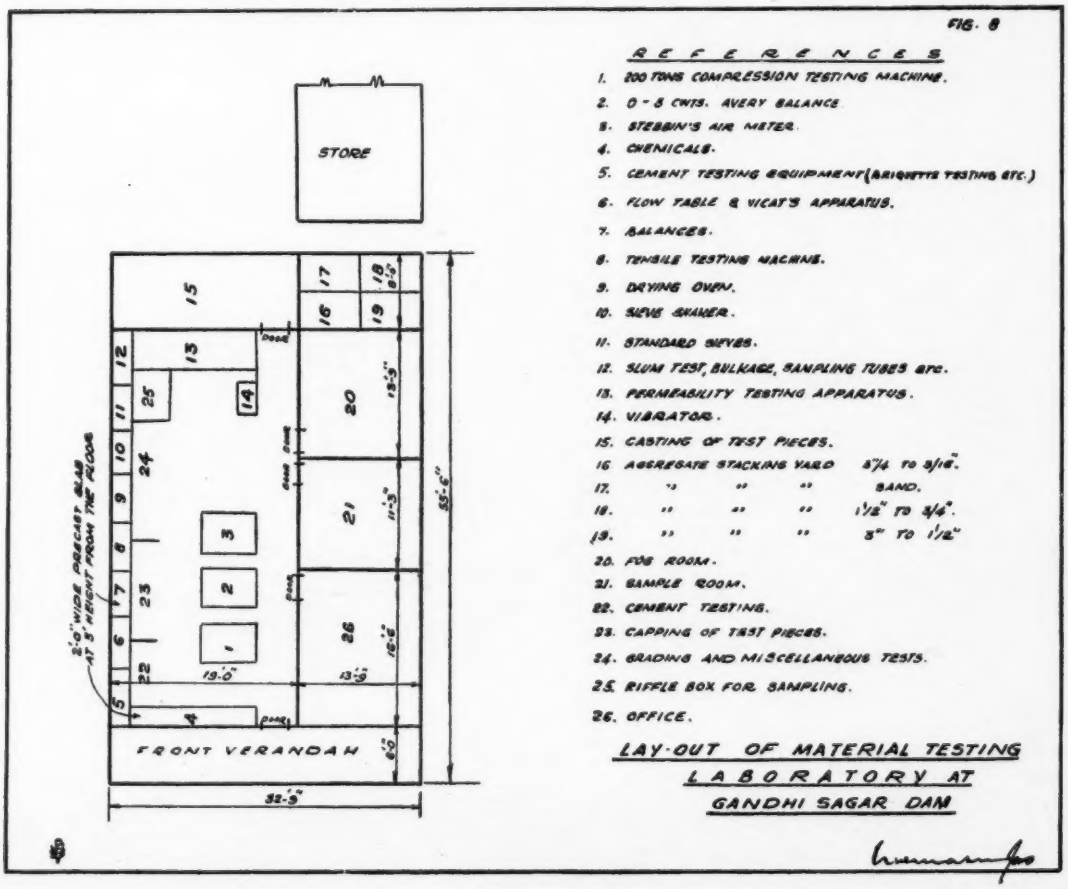


FIG. 8
STORE
FRONT VERANDAH
32'-9"
35'-6"
19'-0"
13'-9"
2'-0" WIDE PRECAST SLAB AT 3' HEIGHT FROM THE FLOOR
REFERENCES
1. 200 TONS COMPRESSION TESTING MACHINE.
2. 0 - 5 CWTS. AVERY BALANCE
3. STEBBIN'S AIR METER.
4. CHEMICALS.
5. CEMENT TESTING EQUIPMENT (BRIQUETTE TESTING ETC.)
6. FLOW TABLE & VICAT'S APPARATUS.
7. BALANCES.
8. TENSILE TESTING MACHINE.
9. DRYING OVEN.
10. SIEVE SHAKER.
11. STANDARD SIEVES.
12. SLUM TEST, BULKAGE, SAMPLING TUBES etc.
13. PERMEABILITY TESTING APPARATUS.
14. VIBRATOR.
15. CASTING OF TEST PIECES.
16. AGGREGATE STACKING YARD 3/4 TO 3/16".
17. " " " SAND.
18. " " " 1 1/2" TO 3/4".
19. " " " 3" TO 1 1/2"
20. FOG ROOM.
21. SAMPLE ROOM.
22. CEMENT TESTING.
23. CAPPING OF TEST PIECES.
24. GRADING AND MISCELLANEOUS TESTS.
25. RIFFLE BOX FOR SAMPLING.
26. OFFICE.
LAY-OUT OF MATERIAL TESTING LABORATORY AT GANDHI SAGAR DAM

over production of concrete and mortar. The evaluation of the data by this method gives a more accurate picture of the results and is useful for design of mixes. Table VI shows at a glance the standard deviation and coefficient of variation obtained for each class of mix.

From the above, it may be seen the degree of control lies between "Excellent" and "Good".

EQUIPMENT

The Laboratory is well-equipped with modern equipment for various essential tests required to be

(Contd. on p. 99)

TABLE 6.

Concrete:

Class of mix.	Cement red cement in pounds/cyd. or (kg/m³)	Test piece.: 6″ × 12″ cylinder.										
		28 days.					91 Days.					
		Crushing	Strength	Standard	deviation	Coefficient of variation	Crushing	Strength	92 days. Standard	deviation	Coefficient of variation
1	2	P.S.I. 3	kg/cm² 4	P.S.I. 5	kg/cm² 6	7	P.S.I. 8	kg/cm² 9	P.S.I. 10	kg/cm² 11	12
A_2 (2500 PSI-3″)	380 (225)	2523	176.6	321	21.47	12.72%	2871	201	322	22.5	11.22%
B_1 (3,000..3″)	460 (272.5)	3068	214.7	392	27.44	12.8%	3393	237.8	369	25.3	10.88%
B_2 (3,000..1½″)	525 (310.8)	3008	210.6	364	25.48	12.1 %	3460	243.2	347	24.3	9.74%
B_3 (3,000..¾″)	590 (349.3)	3330	233.1	418	29.26	12.54%	4050	283.5	368	25.8	9.08%

Mortar:	Volume Batching	Crushing T/□′	strength kg/cm²	Standard T/□′	deviation kg/cm²	Coefficient of variation	Crushing T/□′	strength kg/cm²	Standard T/□′	deviation kg/cm²	Coefficient of variation
1: 2.75	—	169.3	186.0	18.8	20.6	11.2%	211.9	232.5	18.65	20.4	8.8%
1: 4	—	135.5	149	16.5	18.2	12.17%	165.1	180	16.62	18.2	10.07%
1: 5	—	106.6	117	17.67	19.4	16.58%	135.5	149	13.95	15.3	10.3 %

Chambal Canal System in Madhya Pradesh

By Y. G. MANE

THE Canal System for irrigation in Madhya Pradesh forms an integral part of Chambal Valley Development. Out of 14 lakhs acres to be irrigated, the canal system in Madhya Pradesh will cater for 7 lakhs acres annually in the northern most district of Madhya Pradesh in 9 tahsils covered by two districts, i.e. Bhind and Morena. A general idea of the canal system is given in figure I.

The construction of the canal system in Madhya Pradesh was started in the beginning of 1955. The benefit will start accruing from the year 1960-61. The full canal system will be ready by March, 1964 to cater the whole culturable command area of about 11.4 lakhs acres which works out to about 7 lakhs acres of irrigable areas with an intensity of irrigation of about 70 per rent of C.C.A.

The irrigation canals take off from the barrage built across the Chambal River near Kota whereas at the 3 reservoirs on the upstream, i.e., Gandhi Sagar, Rana Pratap Sagar and Kota Dam reservoir water is stored and utilised only for power generation. The Left Main Canal is completely in Rajasthan territory whereas the Right Main Canal with a head discharge of 6,840 cusecs runs for the first 80 miles in Rajasthan territory before it enters the Madhya Pradesh State.

UPPER MAIN CANAL

The Right Main Canal at its 81st mile crosses the border of Rajasthan and Madhya Pradesh across river Parvati with a discharge of 3,900 cusecs. The Canal passes over the river through an aqueduct. The bed width of the Canal at Parvati crossing is 126 ft. with a F.S.D. of 9.50 ft. and the R.L. of the bed of the canal is 770.60. This is a contour canal running to a distance of 112 miles, irrigating an area of 1,75,000 acres of C.C.A. of land. The canal crosses many major rivers and drainages across which structures were being built to carry the canal discharge over these natural drains. The approximate cost of this canal is Rs. 10.649 crores including the distributary system. At its 112th mile this canal, Ambah Branch, designed to carry a discharge of 1,077 cusecs at the head, takes off. The canal with the remaining discharge of 1,900 cusecs continues as Lower Main Canal.

LOWER MAIN CANAL

This canal which is the continuation of the Upper Main Canal from its 112th mile carries a discharge of 1,900 cusecs with a bed width of 83 ft. and F.S.D. 8.00 ft. at its head. The bed R. L. at its head is 645.09. This is also a contour canal running to a length of 33 miles irrigating an area of 1,12,000 acres upto its tail end. The total cost of this canal is about Rs. 1.72 crores including distributary system. At the end of this canal another branch, Morena Branch Canal, takes off with a head discharge of 362 cusecs and the remaining discharge of 1,166 cusecs is led into the Asan river through an outfall channel. This discharge is to be picked up lower down to be fed into the Bhind Canal System which is already existing under Sank-Asan System now to be remodelled for the additional discharge.

AMBAH BRANCH CANAL

This branch taking off from the Upper Main Canal at its 112th mile, carries a discharge of 1,077 cusecs to irrigate an area of 3,21,000 acres which is lying on the ridge between Kunwari and Chambal rivers. At the head the bed width is 73.00 ft., F.S.D. 6.00 ft and bed R.L. 646.09. This is a ridge canal running to a length of 89 miles. The cost of this branch including distributary system is Rs. 1.701 crores.

The following are the number of structures coming under the Upper Main Canal, Lower Main Canal and Ambah Branch.

Sl. No.	Name of structure	Upper Main Canal	Lower Main Canal	Ambah Branch	Total
1.	Aqueduct	15	6	—	21
2.	Syphon aqueduct	18	1	—	19
3.	Canal syphon	3	—	1	4
4.	Drainage syphon	40	14	—	54
5.	Drainage culvert	41	3	—	44
6.	Superpassage	—	1	—	1
7.	District road bridge	6	4	3	13
8.	Village road bridge	44	26	54	124
9.	Railway crossing	5	1	1	7
10.	Head regulator	—	—	1	1
11.	Head sluice of distributaries	63	26	62	151
12.	Cross regulator	4	1	2	7
13.	Escapes	2	1	2	5
14.	Falls	3	3	15	21
15.	Village road bridge cum fall	—	—	22	22

16.	Standing wave flumes	1	2	—	3
17.	Canal crossings	3	1	—	4
18.	Diversion walls	2	—	—	2
19.	Other ancilliary works	2	—	—	2
		252	90	163	505
	Length of canals	112 miles	33 miles	89 miles	234
	Average length of canal between structures	2200′	1800′	2700′	2300′

So it is seen that more than 2 structures are to be constructed for every mile length of the canal and this gives an idea of the terrain in which the Chambal Canal is to pass through.

MORENA BRANCH CANAL

This canal taking off at the 33rd mile of Lower Main Canal carries a head discharge of 362 cusecs to feed an area of 1,03,000 acres for irrigation. This branch is a ridge canal feeding the area between Kunwari and Asan rivers. The length of the canal is 35 miles. The approximate cost of the canal is Rs. 38.11 lakhs including the distributary system.

BHIND BRANCH CANAL

The present Sank-Asan System and Bhind Canal System consists of 2 reservoirs, viz., Pagara in Morena district across Asan river and Tigra in Gwalior district across Sank river. But mostly Tigra water is not available for this canal system as it is utilised around Gwalior town. The Pagara water is picked up by Kotwal weir about 32 miles downstream of Pagara Dam while Tigra water is picked up by Pillowa weir about 22 miles downstream of Tigra Dam. These two weirs are linked by a connecting channel 2 miles long and the head regulator of this system is located at Pillowa weir. The water so led into the Asan river at the downstream of Pagara Dam, is picked up by the Kotwal weir and passed on to Sank river through the connecting channel where it is picked up again at Pillowa weir. This water is fed into the existing Bhind Canal System through the existing regulator.

Drainage Culvert built at R.D. 216800 of Right M.C. Upper.

The existing system is hardly irrigating 85,000 acres of culturable command area annually out of the total culturable command area of nearly 3 lakhs acres available. The remodelled Bhind Canal System will irrigate about 3 lakhs 17 thousand acres including the area under Mau Branch which takes off at 5th mile of this Branch. The length of the Bhind Branch Canal is 52 miles and the head discharge is 1,560 cusecs out of which a discharge of 347 cusecs is led into the Mau Branch. The bed width is 70 ft., full supply depth 8 ft. and the bed R.L. 539.00 ft. at the head of this branch.

The approximate cost of remodelling of this branch is Rs. 52 lakhs.

MAU BRANCH

As earlier explained, this branch takes off at 5th mile of Bhind Branch and carries a head discharge of 347 cusecs irrigating about 99,000 acres of culturable command area of land in Gohad and Mehgaon tahsils of Bhind district. This branch is the same 1-R distributary of the existing Bhind canals now to be remodelled and extended towards Mau lying towards the south of Basali river with additional discharge. The length of this branch is 38 miles. The approximate cost of this branch is Rs. 40 lakhs.

SOIL SURVEY

Soil surveys of the commanded area were carried out on the basis of profile samples collected on six mile grid upto 10′ depth. These soil samples were analysed for clay percentage, pH value, total soluble salts and calcium carbonate, percentage. On the basis of the aforesaid factors, the soils of the commanded area have been grouped into five irrigation suitability classes as follows:

Class:—I Sandy loam with low pH and salt content (areas having less than 0.2 per cent salt content pH less than 9 and clay content less than 17.9 per cent).

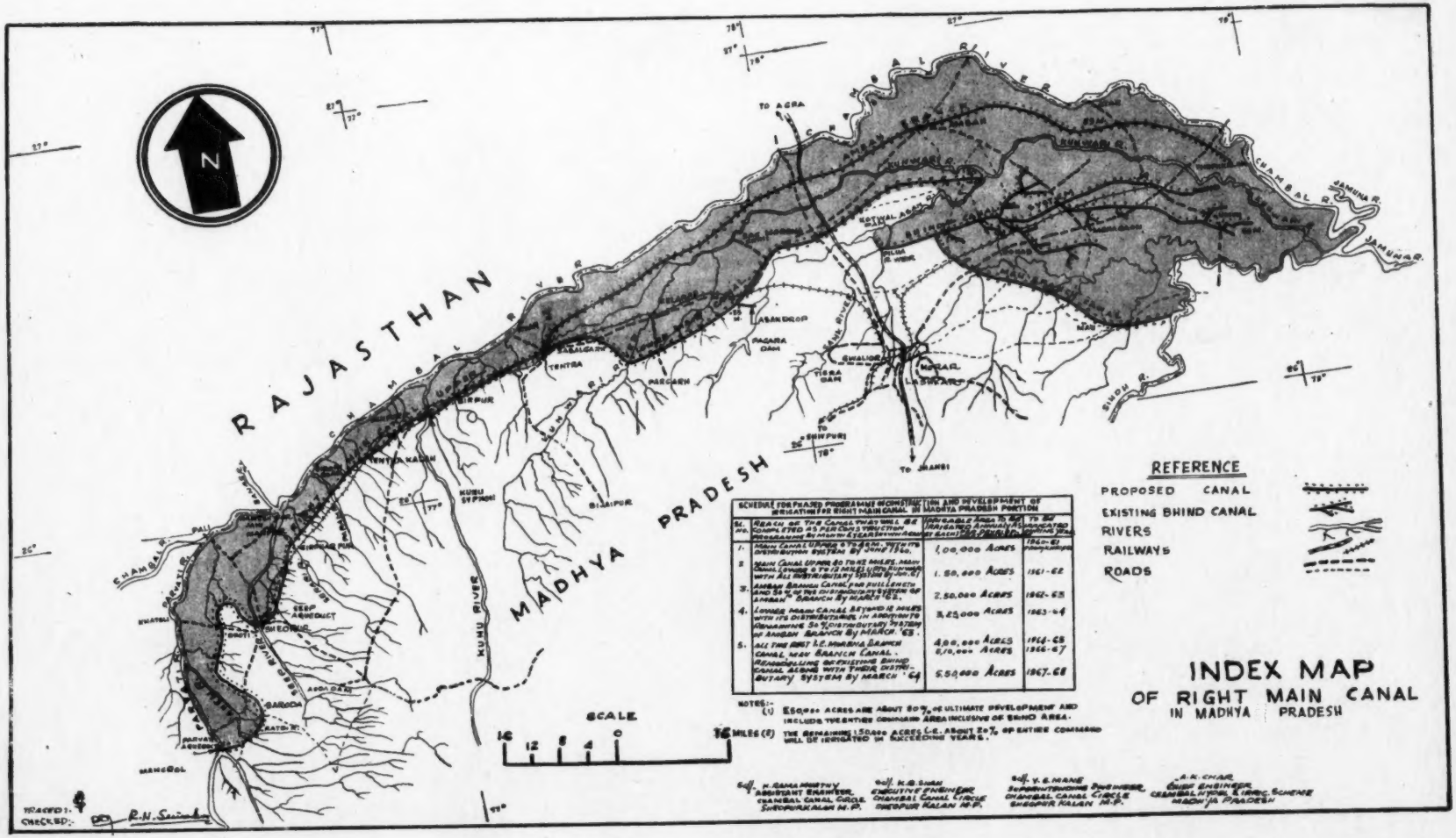
Class:—IIA Sandy loam to loam with low pH and salt content.

Class:—IIB Clay loam with low pH and salt content.

Class:—IIC Clay to heavy clays with low pH and salt content.

(Areas having less than 0.2 per cent salts, pH below 9 but clay more than 17.9 per cent).

Class:—III Clay loam with low pH and high salt content. (Areas having salts more than 0.2 per cent).



REFERENCE

PROPOSED CANAL
EXISTING BHIND CANAL
RIVERS
RAILWAYS
ROADS

SCHEDULE FOR PHASED PROGRAMME OF CONSTRUCTION AND DEVELOPMENT OF IRRIGATION FOR RIGHT MAIN CANAL IN MADHYA PRADESH PORTION

Sl. No.	Reach of the Canal that will be completed as per Construction Programme by end of the year	Cultivable Area to be irrigated annually (Approximately)	To be completed by (Financial Year)
1.	Main Canal upto 67.0 Kms. with its distribution system by June '61	1,00,000 Acres	1960-61
2.	Main Canal upto 80 to 112 miles, main Canal upto 67.0 Kms. with its distributory system by Dec. '61	1,50,000 Acres	1961-62
3.	Amjhar Branch Canal for full length and 50 % of the distributory system of Amjhar Branch by March '62.	2,50,000 Acres	1962-63
4.	Upto 112 miles Main Canal beyond 112 miles with its distributaries, in addition to remaining 50 % distributary system of Amjhar Branch by March '63.	3,25,000 Acres	1963-64
5.	All the rest i.e. Morena Branch Canal, Main Branch Canal. Remodelling of existing Bhind Canal along with their distributary system by March '64	4,00,000 Acres 6,10,000 Acres 5,50,000 Acres	1964-65 1966-67 1967-68

NOTES:-
(1) 650000 acres are about 80 % of ultimate development and includes the entire command area inclusive of Bhind area.
(2) The remaining 150000 acres i.e. about 20 % of entire command will be irrigated in succeeding years.

INDEX MAP
OF RIGHT MAIN CANAL IN MADHYA PRADESH

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Checked by: R.N. Saxena

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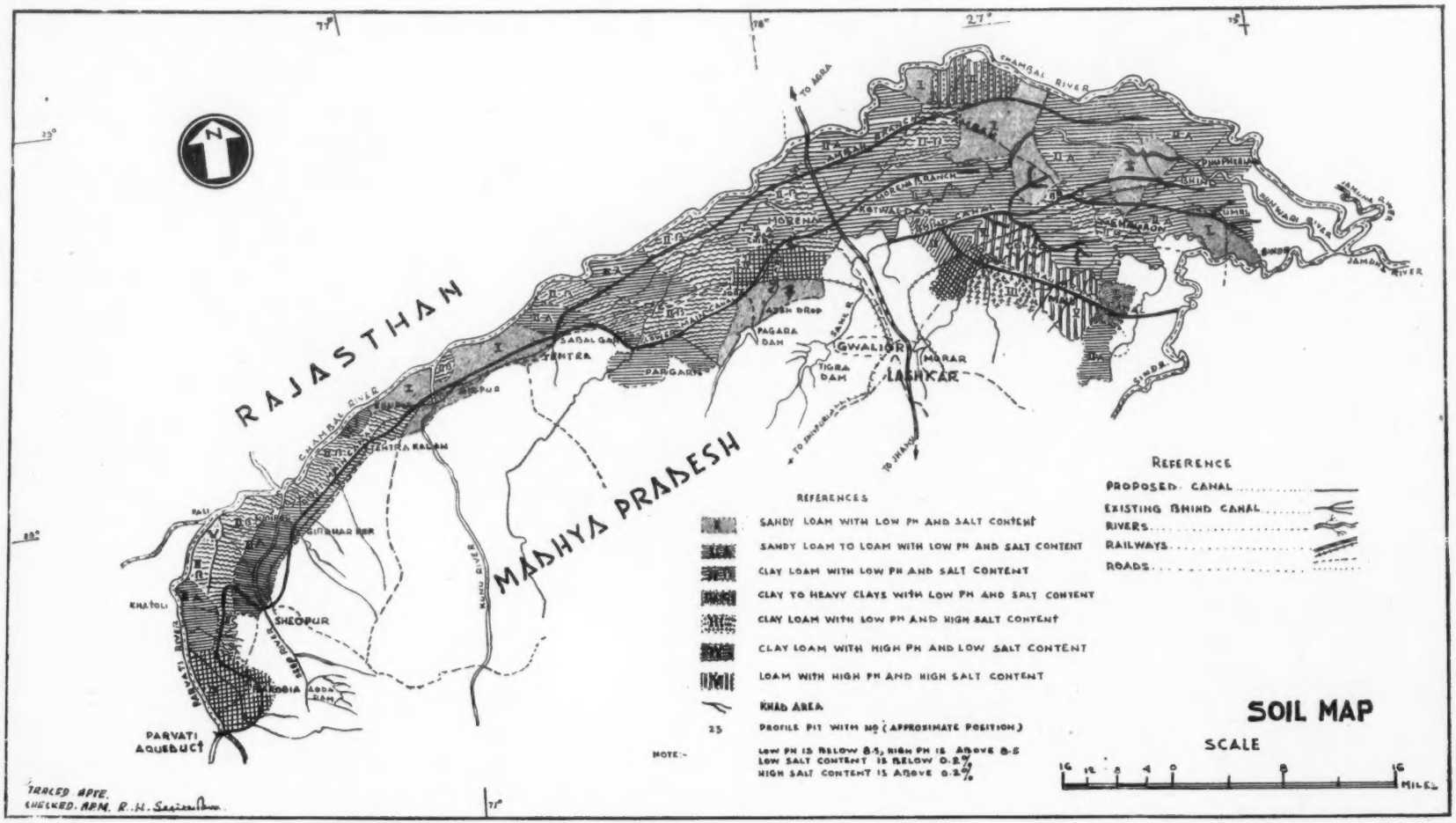
Sd/- V.G. Mane, Superintending Engineer, Chambal Canal Circle, Bhopal Kalan M.P.
Sd/- A.K. Char, Chief Engineer, Chambal Hydel & Irrig. Scheme, Madhya Pradesh


RAJASTHAN
MADHYA PRADESH
CHAMBAL RIVER
TO AGRA
MORENA
GWALIOR
LASHKAR
MORAR
SABALGARH
PARGARH
PAGARA DAM
TIGRA DAM
SHEOPUR
SESLI
KHATOLI
PARVATI AQUEDUCT
KALKODIA
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REFERENCES
SANDY LOAM WITH LOW PH AND SALT CONTENT
SANDY LOAM TO LOAM WITH LOW PH AND SALT CONTENT
CLAY LOAM WITH LOW PH AND SALT CONTENT
CLAY TO HEAVY CLAYS WITH LOW PH AND SALT CONTENT
CLAY LOAM WITH LOW PH AND HIGH SALT CONTENT
CLAY LOAM WITH HIGH PH AND LOW SALT CONTENT
LOAM WITH HIGH PH AND HIGH SALT CONTENT
KHAD AREA
PROFILE PIT WITH NO (APPROXIMATE POSITION)
NOTE:-
LOW PH IS BELOW 8.5, HIGH PH IS ABOVE 8.5
LOW SALT CONTENT IS BELOW 0.2%
HIGH SALT CONTENT IS ABOVE 0.2%
REFERENCE
PROPOSED CANAL
EXISTING BHIND CANAL
RIVERS
RAILWAYS
ROADS
SOIL MAP
SCALE
16 12 8 4 0 8 16 MILES
TRACED BY:-
CHECKED. APM. R.H. Sagar

Class:—IV Clay loam with high pH and low salt content. (Areas having only high pH above 9).

Class:—V Loan with high pH and high salt content. (Areas having both high total soluble salt above 0.2 per cent and high pH above 9).

The details of soil zones under the Chambal command are shown in figure II.

The areas having salts higher than 0.2 per cent, pH greater than 9 and clay content more than 17.9 per cent indicate higher values than the permissible limit and need proper crop planning.

The percentage representation of different classes are as follows:—

Class I	15.1%
Class II-A	44.8%
Class II-B	20.9%
Class II-C	4.7%
Class III	3.5%
Class IV	3.5%
Class V	7.5%
	100.0%

This shows that the majority of the area is suitable for irrigation.

IRRIGATION INTENSITIES

The gross commanded area, culturable commanded area and irrigable area in Madhya Pradesh portion are 17.78, 11.44, and 7 lakhs acres respectively. The annual intensity of irrigation is taken about 70 per cent of culturable commanded area, Khariff-Rabi ratio taken as 30:70. Water allowance at canal head has been made at the rate of 6 cusecs per 1,000 acres of irrigable area.

CAPACITY OF CANALS

This depends on the area to be served during the peak demand period and the water requirements of crops standing during that period. The areas to be served by various distributaries have been collected under various classifications available in revenue record. The culturable area was thus ascertained for each distributary separately. For the purposes of design of canal capacities, 70 per cent of the culturable area has been taken as irrigable. For finding out the overall water allowance, a rough overall crop pattern in the area has been taken as 70 per cent Rabi, 20 per cent rice, 5 per cent sugarcane and garden crops and 5 per cent cotton. This crop pattern is based on the existing cultivation practice in this region. The change in pattern due to increased facilities of canal irrigation has also been taken into account while determining the crop pattern. A number of working tables were prepared to study the most economical utilisation of water for power and irrigation sectors. The following capacity factors were finally agreed upon to have the maximum benefits in power and irrigation sections.

Straight Glais type fall combined with village Road Bridge on Ambah Branch.

CAPACITY FACTORS

Month	*For Irrigation*
October	0.90
November	0.80
December	0.50
January	0.50
February	0.70
March	0.50
April	0.40
May	0.60
June	0.60
July	0.20
August	0.20
September	0.50

The water allowance of 6 cusecs per 1,000 acres at the canal head will give a total depth of 29″ for Rabi and 36″ for Khariff including overlap of Khariff and Rabi.

The detailed crop pattern under various zones of the commanded area are being decided on the basis of the detailed soil surveys done after taking into account factors like climate, topography, depth of underground water table, intensity of rainfall for the last 20 years, drainage problem, facility of transport, current cultivation practice, composition of soil and availability of labour. The detailed crop pattern will however be guided by availability of water as per the overall crop pattern.

ALIGNMENTS

The whole commanded area has been contoured and alignments for the various channels have been marked, with the irrigation boundary on 4″-1 mile survey of India topo sheets having 1′ contour intervals. In the case of contour canals, as far as practicable, the canal has been taken in balanced cutting. In rocky reaches, the alignments have been guided by economical considerations, trying to keep the

total cost of excavation in rock and lining to the minimum. The contour canals cross a number of drainages for which suitable crossings have been selected while aligning the Canal.

DESIGN OF CANAL SECTIONS

The Canal where it enters Madhya Pradesh territory near Parvati river carries a discharge of 3,900 cusecs, with a bed width of 126 feet and F.S.D. 9.5′. The Canal section varies as the discharge gets reduced from section to section due to draw-off in the distributaries and losses due to absorption, evaporation etc. Since only stored water free of silt is being used for irrigation, the canal has been designed using Kutter's coefficient for the rugosity of the channel providing maximum velocity the soil could stand without scour. With the following values of 'n' in Kutter's formula, the earth sections do not vary very much from the Lacey's section for the same velocity and the area of cross-section:

Large channels for discharges above 1,000 cusecs 'n' = 0.02

For discharge below 100 cusecs 'n' = 0.0225

For designing sections in rock cut 'n' is taken to be 0.016, sides being plastered masonry and bed in 1:3:6 cement concrete smooth finished.

In earthen section of main canal, the bed slope has been kept at 1 in 10,000 to give velocity of 3 ft. per sec. Where the alignmnet runs in a curve, allowance has been made for additional loss of head at the rate of $\frac{V^2}{2g} \times \frac{L}{90}$ where V is the velocity of the water in canal and L is the deflection angle of the curve.

In rocky strata, a steeper bed slope (of 1 in 2,500) is given consistent with control levels at some obligatory points. The velocity in rock cut is increased to over 6′/sec. and the canal section is reduced correspondingly. F.S.D. is kept at 10.2 ft. and bed width is reduced to 45′.

Since the canal winds round spurs and valleys, curves are unavoidable but are kept as far as possible flat and no curve is more than 2°. The side slopes of canal in cutting is 1:1 and in embankment, the slope is 2:1. In rock, the side slopes are kept as 1/4:1. In partial cuttings a side berm equivalent to the depth of cutting is provided between the toe of the embankment and edge of cutting. Where cutting exceeds F.S.D.+3′, an additional berm at F.S.D. equal to F.S.D./2 is provided at F.S.L. A minimum of 3 ft. of cover is provided for the banks over the saturation gradient of 4 to 1. The free board between the F.S.L. and the top of the bank is kept as 3′ A service road on left bank 20′ wide including 4′ dowel and an inspection path on the right bank 10′ wide with 4′ dowel are provided. For banks over 12′ high, the right bank has been widened to 16′ including 4′ dowel and free board is increased to 4′. Banks over 19′ in height are provided with filter blankets. Approach banks to aqueducts have been provided with rock fill toes.

The earthwork has been kept at minimum by resorting to balanced depth of cuttings for a considerable length of canal. Wherever there is deficit of earth for banks, the same is lead by machinery from surplus reaches thereby avoiding external borrow pits which is a special feature in this canal system. This also will help in minimising malaria hazards. The canal in rocky reaches is lined to minimise seepage losses and to allow for higher velocities. The bed of the canal in restricted section is proposed to be lined with 4″ thick 1:3:6 C.C. The sides of canal in rocky areas are lined with 1′ thick rubble masonry. Full retaining sections in rubble masonry have been provided above rock level with 6″ thick coping in 1:3:6 cement concrete. The sides of the lined canal are plastered with 1″ thick cement mortar 1:4. Free board in lined canal is kept as 2′. Expansion joints have been provided in side masonry and bed concrete at suitable intervals.

STRUCTURES ON CANAL SYSTEM

The importance of designs and construction of the canal structures can be ascertained from the fact that the cost of these structures will cover nearly 50 per cent of the expenditure of the full canal system. The designs for the structures across main canal and branches were entrusted to Central Water and Power Commission except for Parvati Aqueduct and Kunu Syphon. For these two works, the designs and construction were responsibilities of the contractors. The designs for the structures on distributary system were taken up by the project staff. In the rocky reaches of the main canal where the good masonry stones are available in plenty, stone masonry is invariably used. In other places reinforced cement construction has been adopted. Mostly all along in the canal area good sand stone and sand are available from the bed of the rivers. The general idea of the type and design of structures proposed on the main canals and branches is given in the following paras.

REGULATION WORKS

(A) *Head regulators*:—Head regulators have been proposed at the head of Ambah Branch, Morena Branch and Mau Branch canals. The existing head regulators for Bhind Branch will be remodelled to take the additional discharge for the different full supply conditions.

These head regulators are generally designed as submerged or free flow weirs depending upon the full supply conditions of the off-taking channel, and intermediate piers have been provided having vent ways of 8′ width with shutter arrangement operated

by screw gear system. An operating platform and a road bridge are also provided over the piers.

(B) *Escapes*:—The escapes are generally provided at the upstream of major structures to empty the canal D/S in the case of emergencies, without affecting the irrigation of the lands lying on the upstream. One escape with a cross regulator is provided at the upstream of Parvati Aqueduct before the canal enters Madhya Pradesh State to regulate the discharge entering the Madhya Pradesh portion of Chambal Canal. Escapes with cross regulators have also been provided at the 40th and 85th miles of Upper Main Canal on the upstream of major structures, i.e. Seep Aqueduct, and Kunu Syphon. One escape with a cross regulator is proposed at the 9th mile of Lower Main Canal and two on the Ambah branch canal in keeping with the development programme.

The escapes are mostly designed as partly submerged weirs with intermediate piers and regulating gates of 8ft. to 10ft. width operated by screw gear system. As the escapes on the canal system are located at longer intervals of canal length, they have been designed for the full supply discharge as against the usual practice of designing the same for $\frac{1}{3}$ full supply discharge.

(C) *Cross Regulators*:—The cross regulators have been provided usually on the downstream of escapes, for the purpose of closing the canal downstream for emergencies of major repair, etc.; and allowing the water through the escape. These regulators have been combined with the village road bridges and regulating arrangements have been made with iron gates and screw gear system.

CROSS DRAINAGE WORKS

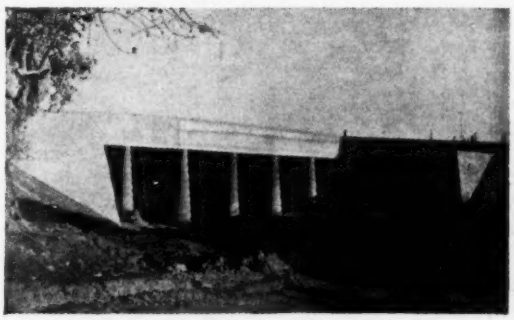
The Upper and Lower Main Canals run for about 145 miles on ground which is traversed by a number of drainages. Provision is made for suitable structures to allow the run-off from these drainages to flow across the canal, without damaging the canal works. To avoid inflow of silt and complications in regulation of the flow of canal, water from these nullas is, in no case, allowed to flow into the canal. In some cases, on economic considerations, nullas have been diverted to the adjoining streams with consequent reduction in the number of structures. In such cases, the ventage for cross drainage is inclusive of the additional run-off. In the Main Canal Upper and Lower, there are 142 cross drainage works, of which 17 are major ones. The biggest cross drainage works are Parvati Aqueduct and Kunu Syphon estimated to cost Rs. 90/- lakhs and Rs. 140/- lakhs, respectively. It is worth mentioning that the Kunu Syphon is a unique structure so far. While designing the type of structure for a particular cross drainage, special attention has been paid to the topography of the country, availability of ventage area depending upon the relative R.L. of drainage bed and canal bed, F.S.L. and H.F.L. of canal and nulla respectively, availability of strata for foundations, availability of materials and labour required for execution of work, etc.

(A) *Aqueducts*:—These structures are built across the rivers to carry the canal discharge over them when the bed level of the canal is well above the high flood level of the stream. Many kinds of aqueducts have been designed depending upon the type of foundations available and the site conditions. The biggest aqueduct on this canal is Parvati Aqueduct which is at the head of the Upper Main Canal. The details of this structure has been dealt in detail elsewhere in this publication.

Most of the aqueducts are of masonry piers for sub-structure with open foundations on hard rock and the superstructure being either R.C.C. trough over 'T' beams or arches in which case the canal is taken over between masonry retaining walls. The arches are also either plane concrete or masonry as the case may be depending upon the availability of good masonry blocks. The canal is flumed over the structure to reduce the cost, and the velocity of the canal water allowed on the structure is upto 10′/sec. as against the velocity of 3′ per sec. allowed in earthen reaches of main canal.

When good rocky foundations are available the span length is kept more and for superstructure R.C.C.T. beams are provided with an R.C.C. duct to carry the discharge. In cases where good rocky foundations are not available, the spans kept shorter and the R.C.C. duct is laid directly over the piers. The waterway is divided into compartments, each of the compartment walls acting as a beam connected at the bottom with the slab. In cases where there is hard rock at higher levels, the piers are founded directly on the rocky strata. But where the rock is not good R.C.C. rafts are provided for pier foundations.

(B) *Syphon Aqueduct*:—Syphon aqueducts have been constructed where the H.F.L. of the drain is above the bed level of the canal. The structure is



View of Aheli Syphon—Aqueduct built at R.D. 306000 on Right M.C. Upper.

Drainage Syphon built at R.D. 280100 of Right M.C. Upper.

similar to the aqueduct, but the supstructure is designed for the uplift pressure of the drainage water. The superstructure slab of the duct is anchored to the abutments and piers with 1″ anchor bars extending in the abutments and piers to a depth of 6′ to 10′.

(C) *Canal Syphon*:—There are only 3 syphons proposed so far for this canal system, all of which are on the Upper Main Canal. The first is across the Kunu River which is one of the biggest prestressed concrete syphon in the world. The design details have been dealt separately elsewhere in this publication.

The other two canal syphons are of box type barrels wherein the canal is flumed by means of smooth transition. The drainage discharge passes over the barrels in an R.C.C. trough. All the wing walls for the drains, flume walls, the canal and road piers are of masonry in cement mortar 1:5 The canal is depressed below the drain bed level with gradual slope on either side.

(D) *Drainage syphon*:—Most of the drains have been syphoned out below the canal bed. In the reaches where the soil is available for foundation with a safe bearing capacity of at least 1.5 tons/sft, R.C.C. box type barrels have been constructed to syphon out the drainage discharge by deepening the drainage bed below the canal bed level. The training of the nullah has been done on the downstream of the structure for the syphon to function properly. Many of the drains have been combined by means of diversion channels and a syphon is provided across the canal at a suitable place depending upon the economy of providing diversions over that of providing independent structures. The structure is provided for the full width of the canal including the banks without restricting the canal width.

Where good rock foundations are available, the syphon is built with masonry abutments and piers with R.C.C. slabs over them, which are anchored to the piers and abutments with 1″ diameter anchor bars taken down below the foundation levels. Figure VI shows such a type of syphon built at 57th mile of right main canal upper. If the drainage is sufficiently big, the fluming of the canal is also done with R.C.C. trough for the canal water.

(E) *Drainage culvert*:—Drainage culverts are provided when the H.F.L. of the drain is well below the bed level of the canal. The structure is built to the full width of the canal including the banks, in earthen reaches of the canal. In rocky reaches the same restricted section passes over the culvert with side retaining walls. In a very few cases hume pipes are provided for the drainage syphon and the canal is taken over the pipe between masonry retaining walls and the road is taken outside the retaining wall.

The foundations are generally open ones laid on good soil or on rocky beds and in a few cases when the soil was found not good, R.C.C. rafts have been provided. The piers are of masonry in C.M. 1:5 and the superstructure consists generally of arches in plain concrete or masonry. But where sufficient headway is not available R.C.C. slab has been provided.

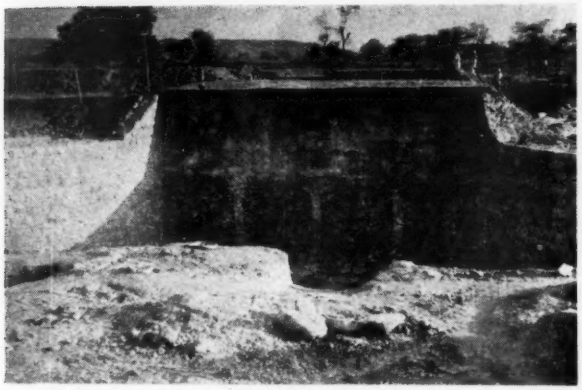
(F) *Super Passage*:—Super passages are very rare in this canal system and there are only two structures proposed so far on the lower main canal where the F.S.L. of the canal is quite below the H.F.L. of the drain. The canal has been taken in full width through a number of ventways of 10′ width and 8′ height formed by the intermediate piers over which an R.C.C. slab rests to carry the drainage discharge between masonry retaining walls. The piers in the canal vent way are of masonry in C.M. 1:5 plastered with $\frac{1}{4}$″ thick cement mortar 1:3 for effecting smooth flow of the canal water. The drainage is flumed over the canal to attain a maximum velocity of 10.35′ per sec.

FALLS

Most of the falls on the canal system are located on the Ambah Branch which is a ridge canal. Mainly there are 3 types of falls provided and a brief description of these types of falls is given as detailed below.

(A) *Vertical type of falls*:—This type is provided only for 1′ drop in canal bed. The structure consists

Seep Aqueduct built at R.D. 19700 of R.M.C. Upper.



Drainage Syphon built on Right Upper M.C.

of a masonry wall with 2.5′ top width at the crest taken down and founded at about 5′ below the bed level. The crest level is kept above the bed level depending upon the depth of flow required above the crest to pass the F.S. discharge. On the downstream a cistern of about 8′ to 10′, width is provided with its floor level at about 6″ below the downstream bed level. No restriction of the canal bed width is affected.

(B) *Straight glacis type Fall*:—This type of fall is provided for the falls less than 4 ft. It consists of an U/S glacis of ½′ to 1′ slope, a crest of about 30″, D/S glacis of of 2:1 slope and a cistern on the D/S side kept at 1′ below the downstream bed level with 4 rows of friction blocks for the full width of the canal. The canal is flumed in this case. In many cases village road bridges are combined with the falls and the intermediate piers are provided in the restricted portion. Figure VIII shows the details of one of this type of fall.

(C) *Baffle type fall*:—Where the fall is 4 ft. and above, this type is provided. The structure consists of upstream glacis of ½′ to 1′ slope, crest of about 30″ width, downstream glacis of 2/3:1, a baffle wall and cistern at about 6″ below the downstream bed level. The canal is flumed in this case also and village road bridges have been combined wherever possible.

CROSS COMMUNICATION WORKS

Wherever the canal crosses the major district roads, arterial road bridges are provided with a roadway of 22 ft, designed for class A loading as per the I.R.C. standards. Similarly road bridges for many number of village roads are also provided at a minimum rate of one bridge for every one or two miles for the main canal depending upon the importance of the roads crossing the main canal. This distance has been reduced to one mile for branches and distributaries. This is designed with a roadway of 22 ft, for I.R.C. specifications. Figure IX shows one of the District road bridge built on Upper Main Canal.

At many cross drainage works, link bridges have been provided to cross the canal on foot. Road bridges over Ambah and Morena branches for the National Highway (i.e. Agra-Bombay Road) are also proposed.

RAILWAY CROSSINGS

The Main Canal Upper crosses the narrow guage Gwalior-Sheopur railway at a number of places where railway bridges have been proposed. The railway department has designed the bridges. The piers are of either masonry or concrete. The superstructure is of steel girders. An overflow weir on the upstream of every railway crossing has been provided at the F.S.L. to safeguard the superstructure of the railway bridge against any heading up of the water in the canal.

CANAL CROSSING

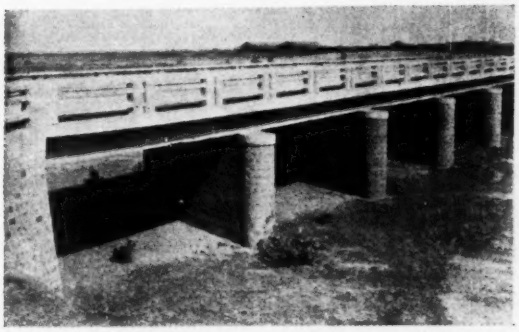
There are about 3 canal crossings wherein the existing minor canals crosses the Chambal Main Canal. These have been taken over the canal in a reinforced cement concrete duct resting on intermediate masonry piers. Village road bridges have also been combined with one or two of the canal crossings.

OTHER MASONRY WORKS ON CANAL SYSTEM

In addition to the above structures there are many types of structures connected with the distribution system similar to structures on Main Canals. To give an idea of the number of structures involved in the distributary system: the distributary system under the first 40 miles of Right Main Canal Upper, alone is provided with about 415 masonry structures in addition to 563 outlets. These structures are under construction and are expected to be completed shortly.

DISTRIBUTION SYSTEM AND UTILIZATION OF WATER

Besides 145 miles of Main Canal, the canal system will consist of about 215 miles of branches and about 900 miles of distributaries and minors. So far



District Board Bridge across Upper M.C.

it is decided to construct minors upto 225 acres of C.C.A. or upto a minimum limit of 1 cusec discharge. Cultivators are to dig channels below this limit. The alignment for water course will however, be furnished on village maps by the department. Generally the cultivators are found delaying in digging the field channels, as observed in similar projects in the country. This results in delayed utilization of water facilities. To avert this situation the Government is seriously thinking of constructing water courses at the cost of the cultivators as well by the department. If it is decided to execute the water courses departmentally, it will go a long way in effecting timely utilization of the irrigation facilities. In addition to the above the following points deserve consideration in order to bring about timely utilization of water which will be made available by the canal system:

Loans to Cultivators. The general standard of cultivators in this region is very poor at present. Demonstration farms have been opened by the Government in this area to teach the ryots by actual demonstration the improved methods of farming, use of improved agricultural implements, use of better seeds and fertilizers, etc. To make these improvements, while changing over from dry cultivation to perennial irrigation, agriculturists will require fresh investment of money in levelling their lands, purchasing necessary tools, seeds and fertilizers. The ryots in this area being poor, will require loan to be advanced in the initial stages. These loans can be recovered later on in easy instalments, when their financial position is improved. Relief by way of exemption from irrigation cess for a few years in the initial stage will also go a long way in timely utilisation of irrigation facilities.

PROGRAMME AND PROGRESS

The entire canal system in Madhya Pradesh is estimated to cost Rs. 1,774.20 lakhs. Out of this expenditure to the end of June, 1960 is about Rs. 985.00 lakhs. The balance of expenditure is programmed to be spent in the next three working seasons.

Out of the total 13,000 lakhs cft., of earthwork involved in the canal system 5,890 lakhs cft. of earthwork has been done upto the end of June, 1960. Out of the total 273 lakhs cft, of rock cut involved, 246 lakhs cft. of rock cut has been done to the end of June, 1960, 135 lakhs cft. of masonry and concrete has been done out of 202 lakhs involved. The balance work is to be completed by the end of March, 1964. As per programme of development of irrigation, 80 per cent of the irrigable area, i.e. 5,50,000 acres are programmed to be irrigated progressively starting from the year 1960-61 upto 1967-68.

CONCLUSION

Irrigation of 7 lakhs acres of land besides yielding additional 2,35,000 tons of foodgrains annually will considerably change the pattern of agriculture in this area. The soil surveys have shown that the majority of land of the command area is well-suited for irrigation. The area going to be benefited by irrigation is prone to frequent famine conditions, thereby draining the revenue of the Government to a considerable extent. The result of such famines is strained economic conditions of people, which, in quite a few cases, lead to anti-social and criminal activities. The benefits which the canal irrigation will bring to these troubled area and to the people will naturally bring in its wake a very desirable change in this aspect, besides raising social structure as a whole.

(Continued from page 50)

LAYOUT OF GANDHI SAGAR SWITCHYARD

ers is that they house the current transformers also in the lower bushing. In the Asea breakers, the current transformers are separately mounted. These are also provided with three secondaries providing a 50 - 100 - 200: 1 transformation ratio.

The utilisation of the three cores of the secondary winding of the current transformers in the generator and line circuit breakers is as follows:

	Generator Unit Circuit breakers	Line circuit breakers
Core 1 30 VA class BM	Nil	Instruments and metering
Core 2 30 VA n > 10	Bus differential protection	Bus differential protection
Core 3 30 VA n > 15	Generator transformer differential protection	Over current parallel feeder and distance protection.

The Galileo potential transformers are of capacity type, i.e., the upper bushing contains a series of condensors connected between line and ground from which a tap at 11 kV is taken to a small core type transformers housed in the lower box.

3. *Other equipment.*—The lightning arrestors are Asea type XAA-120 and are provided with surge counters. The 11 kV power cables are laid in a cable gallery just beneath the transformer rail track and the control cables are brought out from the power station in an adjoining gallery up to the switch house from where they are spread out in the switchyard in surface trenches. The d.c. and a.c. power distribution boards are also located in the switch house near the outdoor switchyard.

Design and Construction of Parvati Aqueduct in Mile No. 1 of Chambal Right Main Canal, Upper, M.P.

By R. K. SUBRAHMANYAM

THE Parvati Aqueduct is situated at the border of both Rajasthan and Madhya Pradesh States. The Chambal Right Main Canal which starts from Kota barrage traverses about 80 miles in Rajasthan, before it enters the Madhya Pradesh territory. This aqueduct provides the link across the river Parvati.

The river Parvati is a tributary of the Chambal and for a major part flows in Rajasthan. The catchment area of the river at the site of the aqueduct is 5,500 sq. miles and the maximum observed discharge is 5,60,000 cusecs. The Right Main Canal is a contour canal and has been so aligned that as far as possible the canal runs in balanced depth of cut and fill. This principle limits the choice of a good site for crossing. A number of cross sections both upstream and downstream of the present aqueduct site were studied but only at this site the ravines to be crossed were a minimum and provided a good crossing with a straight portion of the river. This site was chosen even though there was a pool of water in the river of about 16′-0″ in depth.

The river is torrential carrying heavy flow during the months of June to October. During the other months the flow almost dwindles down to a mere trickle thereby allowing work to be done in the bed of the river for eight months in a year.

IMPORTANT DATA OF THE DRAINAGE, CANAL AND STRUCTURES

(1) *Hydraulic particulars of drainage*

Maximum peak discharge observed at site of aqueduct	— 5,60,000 cusecs
Catchment area at site of crossing	— 5,500 sq. miles
H F.L. observed	— R.L. 746.00
H.F.L. observed assumed	— R.L. 748.00
L.W.L. during dry season	— R.L. 683.00
Bed level at the deeper portion	— R.L. 667.00
Depth of pool of water at site of crossing	— 16 ft.

(2) *Hydraulic particulars of canal on upstream of aqueduct*

Discharge	— 3,900 cusecs
Bed width	— 126 ft.
F.S.D.	— 9.45 ft.
Free board	— 4 ft.
Velocity of flow	— 3.14 ft. per second
Bed slope	— 1 in 10,000 ft.
Inner side slopes of banks	— 2 to 1
Top width of bank — left	— 30 ft.
Top width of bank — right	— 20 ft.

(3) *Details of aqueduct*

Length from abutment to abutment	— 1,507′-6″
Width of duct	— 32 ft.
Spans	— 17 Nos. (12 spans of 107′-3″) (3 spans of 49′-6″) (2 spans of 30′-0″)
Velocity of water in the duct	12 ft. per sec.
Length of flumes	
Entry	— 188 ft.
Exit	— 376 ft.
Fluming	
Entry	— 1 in 4
Exit	— 1 in 8
F.S. level at inlet end of trough	— R.L. 777.31
F.S. level at outer end of trough	— R.L. 775.16
F.S.D.	— 10.2 ft.
Free board	— 1.8 ft.
Bed slope	— 1 in 701.4
Diameter of well *kerb*	— 20′-6″
Outer diameter of wells	— 18′-0″
Diameter of well cap	— 18′-6″
Depth of well cap	— 4 ft.
Top level of well cap	— R.L. 691.00
Diameter of columns for piers with well foundations	— 12 ft.
Diameter of column cap	— 13 ft.
Depth of column cap	— 4 ft.
Top level of column cap	— 752.40
Diameter of columns for piers with open foundations	— 10′-0″
Diameter of column cap for piers with open foundation	— 11 ft.
Road way (Clear)	— 24 ft.

DESCRIPTION OF THE AQUEDUCT

View of the Aqueduct nearly completed is shown in the picture. It is a bowstring girder type supported on circular columns resting on R.C.C. wells. This type of structure was preferred as the heights of the piers are very high and any other type would have required either more number of piers to support the heavy loads or a number of deep beams. Moreover the trial pits indicated that there was coarse sand and warranted the adoption of well foundations as most suitable so that the well could be made to rest on shale available at

R.L. 647.00 i.e. about 40′-0″ from low water level of the river. The structure consists of 12 spans of 107′-3″, 3 spans of 49′-6″ and 2 spans of 30′-0″, thus accounting for 17 spans in all. All the piers except the 1st and the last two are founded on a pair of circular wells which are sunk to the hard layers of quartzite or compact shale. The 12 spans of 107′-3″ consist of two R.C.C. columns of 12′-0″ diameter connected by an R.C.C. diaphragm 9″ thick and 24′ long. Over the columns there is a thick heavy reinforced R.C.C. cap of 4′ depth. Chairs have been provided over these column caps to support the cast steel bearings of the fixed and free ends. The general plan elevation and section of the bridge are shown in Plate I. From that it will be seen that the 32′-0″ wide, trough carrying the water, are supported by deep cross beams which are supported by the bowstring girder at the points where suspenders are located. The suspenders directly transmit the load to the arch. There are two wind ties connecting the two bowstring girders together and these in addition act as beams to carry a road way at this level. Brackets have been provided at suitable levels on suspenders to support twin beams connected by diaphragm which in turn support the road slab. The road way is 24′-0″ clear between curbs with M.S. railing on either side. The road is located in the centre of the trough for balancing the loads. The designs for this structure were furnished by the contractors M/s. Joshi and Verma who were entrusted with the construction. The designs were finalised in consultation with the Central Water and Power Commission, New Delhi.

Piers

Well sinking was first attempted in the wells for piers near the banks. Islands were formed to project about a foot or two above the low water level of the river at that time. In addition to the other advantages this type of forming the islands entirely deleted the necessity for diversion or dewatering which would have been a greater problem especially when a stagnant pool of 16′-0″ depth of water had to be tackled. Cutting edges made of $\frac{1}{4}$″ thick plates with stiffeners were kept on the islands. The wells are of 18′-0″ diameter and have a wall thickness of $16\frac{1}{2}$″ and the kerbs were of 20′-6″ diameter having the shape of a frustrum of a cone. The details of kerbs are given in Plate II .Form-work for the kerbs and a portion of the well were erected on the island and the kerb was concreted. The kerb was allowed to set for a few days before attempting to sink the same. The wells were extended in stages of 6′-0″ as they were sunk. The crab winch worked by a steam boiler was used to dredge the material inside the well. Care was taken to avoid tilting. Sometimes kentledge had to be provided with enough weight for proper sinking.

The above operations could not, however, be carried out successfully. The cutting edges reached hard strata very soon and the crabs could not cut further. Hence dewatering had to be done to inspect the type of strata met with. In case of some of the wells very hard conglomerate was met with and it was very difficult to sink the wells through this strata. Attempts were made to chisel the conglomerate with pneumatic pavement breakers and light blasting was also resorted to. As the strata, though porous, was very hard, much head-way could not be made. So trial pits had to be dug which revealed that the conglomerate layers were very thick and piercing through these layers proved futile. So the wells were plugged at that level itself with 'A' grade cement concrete of 2000 lbs. per square inch compressive strength. In some other wells, especially in the bed of the river the cutting edges were allowed to rest on the hard strata first met with and as the depth of the well sunk were not enough to provide stability to the piers, divers were sent to seal the cutting edges to combat the heavy seepage of water. Treating these wells as mere coffer dams, excavation of jack well was done below these cutting edges going through various strata till a layer of sufficient thickness of hard quartzite or sand stone was met with. In some cases these jack wells have been taken to R.L. 643 about 4′-0″ lower than the designed levels for want of good strata. This method had to be adopted to ensure a proper key into the ground for the piers and also to reach the proper strata which can take the designed load of 6 tons per square foot as the method of well sinking had failed. These jack wells were plugged with concrete of 'B' grade mix with 2250 lbs. per sq. in. compressive strength. This method of well foundations was successfully adopted to suit the changed condition.

Sub Structure

The sub structure consists of 12′-0″ diameter R.C.C. columns, one on each well connected by a diaphragm 9″ thick. The columns have a wall thickness of 18″. The annular space has been filled with cyclopean masonry with 40 per cent plums. As the columns are circular in shape it has dispensed with the provision of cut and ease waters. The diaphragm takes care of lateral stresses that may develop due to wind and current and makes the columns act monolithically. The first and the last two piers which are having open foundations have 10′-0″ diameter columns with a wall thickness of 15″. Over the columns there are heavy reinforced caps of 'B' grade concrete.

Chairs are short rectangular columns which rest over the caps. They afford clearance for arranging centering girders and also for fixing the foundation bolts etc, properly while erecting the bearings, and save the height of piers. The reactions from the superstructure are transmitted to the substructure through these chairs and these induce heavy local stresses. In order to take up these heavy stresses the chairs have been specially reinforced with spirals and have been cast in richer mix of $1 : 1\frac{1}{2} : 3$ concrete giving a cube strength of 4000 lbs. per sq. inch. Plate III

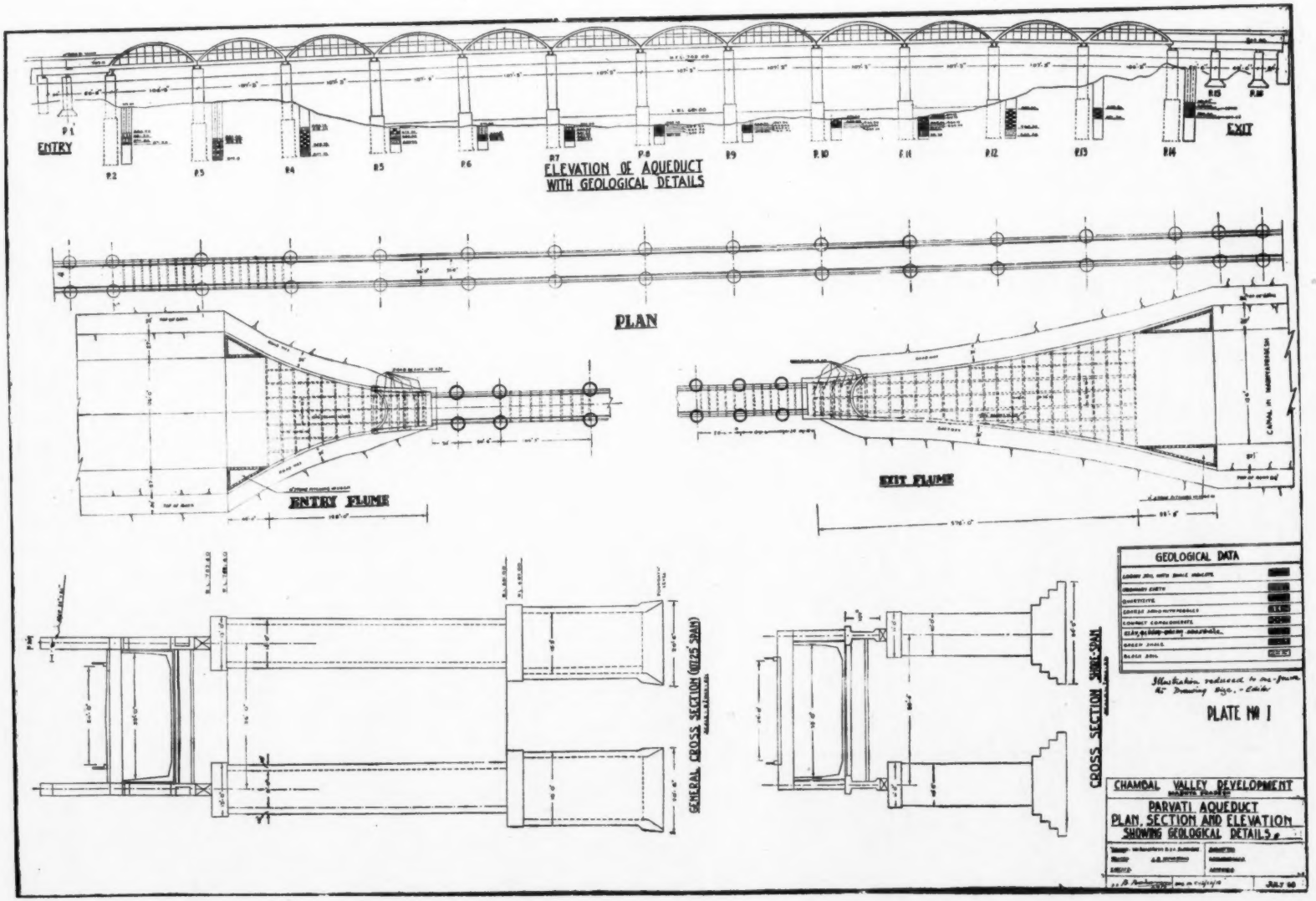
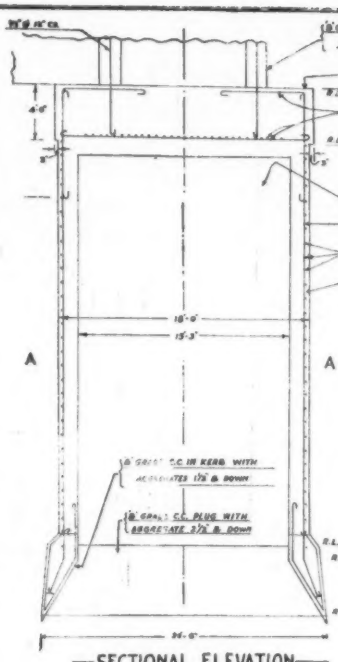
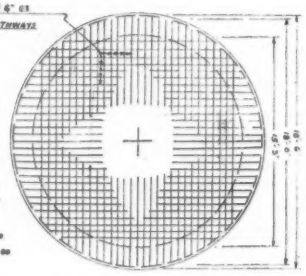

ENTRY
EXIT
ELEVATION OF AQUEDUCT
WITH GEOLOGICAL DETAILS
PLAN
ENTRY FLUME
EXIT FLUME
GENERAL CROSS SECTION (WITH 2 SPAN)
CROSS SECTION SHOWING 2 SPAN
GEOLOGICAL DATA
Illustration reduced to one-fourth of Drawing No. - Civil
PLATE NO I
CHAMBAL VALLEY DEVELOPMENT
PARVATI AQUEDUCT
PLAN, SECTION AND ELEVATION
SHOWING GEOLOGICAL DETAILS
JULY 60

PLATE No II.



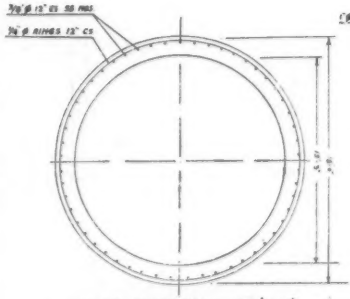
SECTIONAL ELEVATION

SCALE: 1"=4'



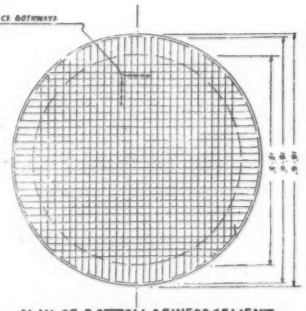
PLAN OF TOP REINFORCEMENT OF WELL CAP

SCALE: 1"=4'



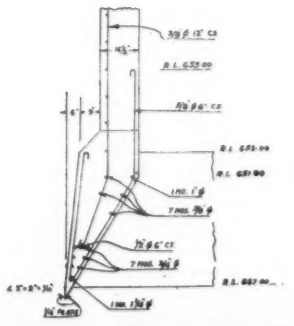
PLAN SECTIONAL AT 'A.A.'

SCALE: 1"=4'



PLAN OF BOTTOM REINFORCEMENT

SCALE: 1"=4'



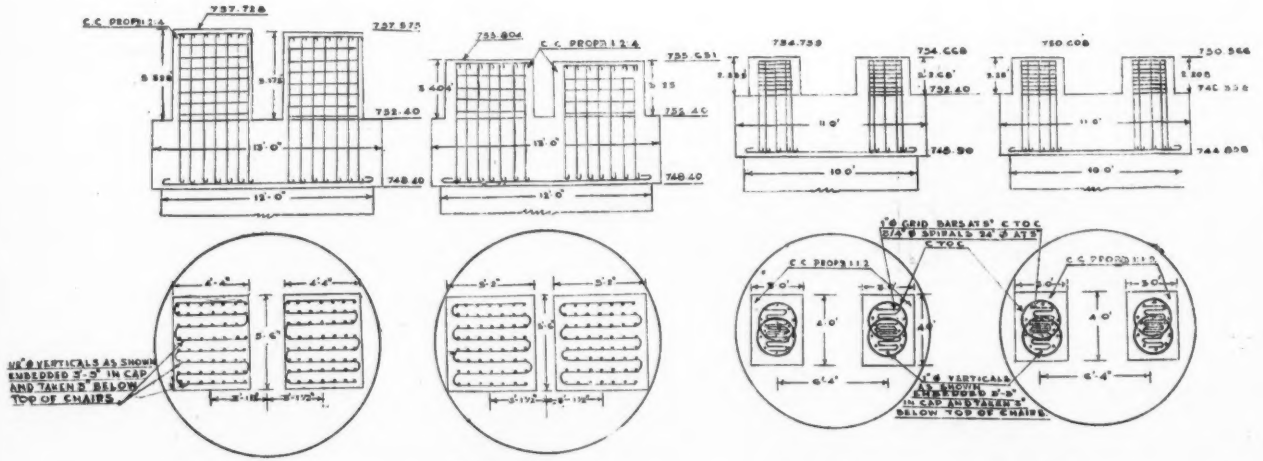
DETAILS OF WELL KERB

SCALE: 1"=1'

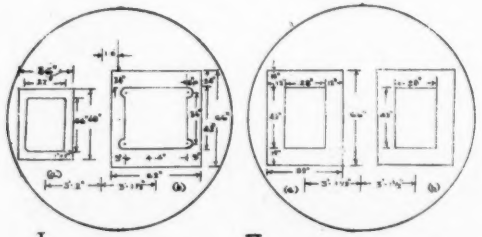
CHAMBAL VALLEY DEVELOPMENT PROJECT

DETAILS OF WELLS WELL-CAPS & WELL KERBS OF PARVATI AQUEDUCT

Illustration reduced to one-third the Drawing Size. Ed.



PIER 5 PIER 6 PIER 15 PIER 16



I II

PLAN SHOWING THE POSTION OF CHAIR WITH THE BEARING

PLAN

I(a) SHOWS CHAIR WITH R.C.C. BEARING BOTTOM BLOCK

I(b) SHOWS CHAIR WITH CAST STEEL FREE BEARING BASE PLATE

II(a & b) CHAIRS WITH CAST STEEL FIXED BEARING BASE PLATE

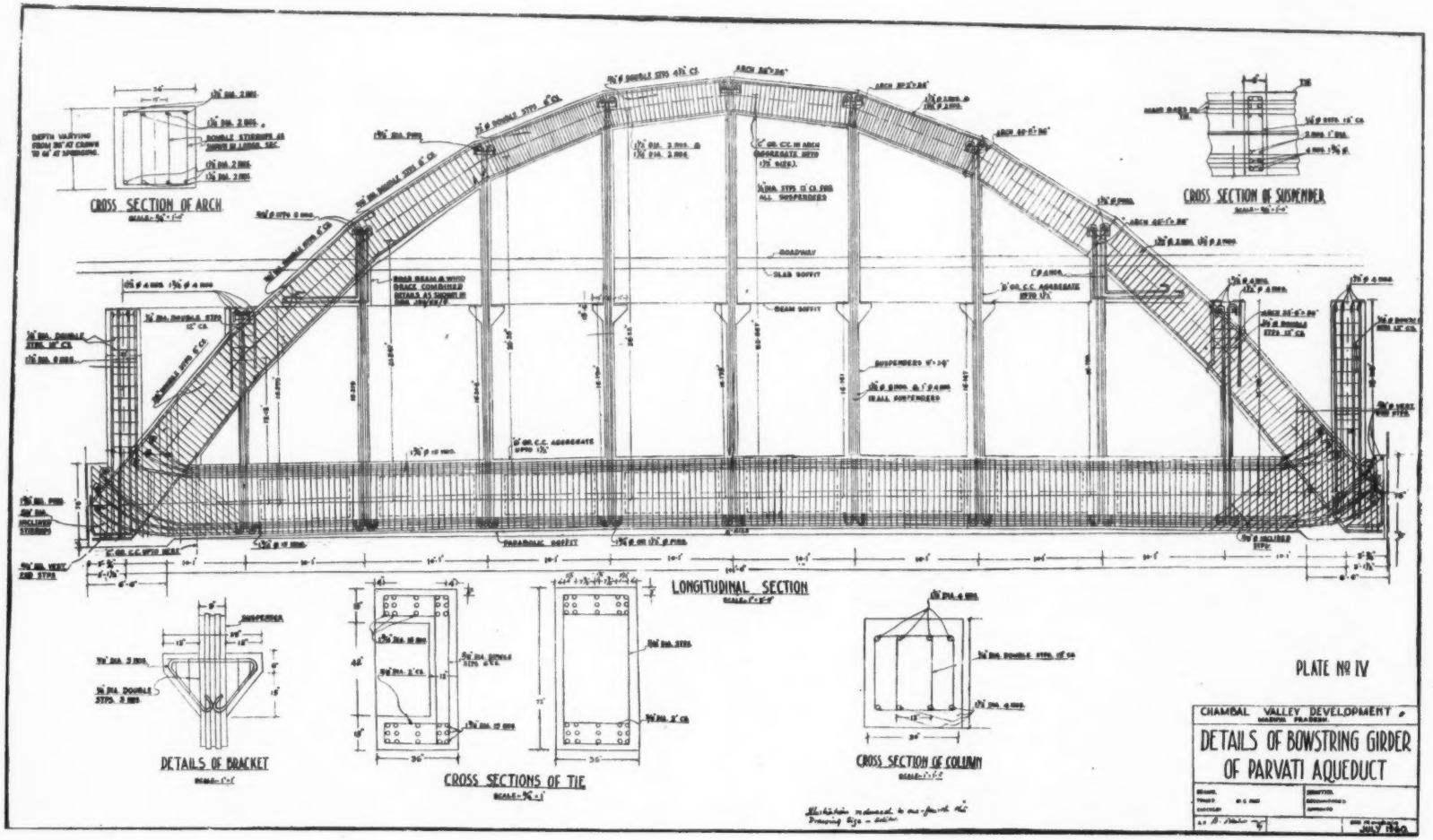
PLATE No. III

CHAMBAL VALLEY DEVELOPMENT
MADHYA PRADESH

DETAILS OF REINFORCEMENT OF CHAIRS OF PARVATI AQUEDUCT.

DRAWN	SUBMITTED
TRACED GAIN. M.C.	RECOMMENDED
CHECKED	APPROVED
A.E. B. Bhalerao	D.R.G. No. C/P/[illegible]

JULY 1960


CROSS SECTION OF ARCH
CROSS SECTION OF SUSPENDER
LONGITUDINAL SECTION
DETAILS OF BRACKET
CROSS SECTIONS OF TIE
CROSS SECTION OF COLUMN
PLATE No IV
CHAMBAL VALLEY DEVELOPMENT
MADHYA PRADESH.
DETAILS OF BOWSTRING GIRDER OF PARVATI AQUEDUCT
JULY 1960

gives the details of reinforcement designed to take up the bursting tension.

Superstructure

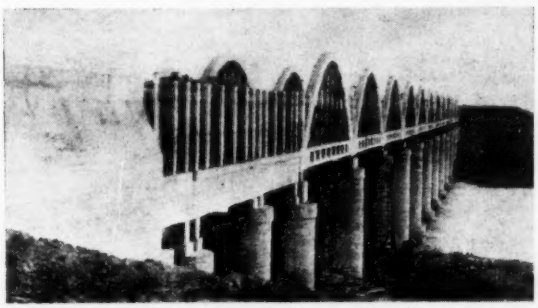
The superstructure consists of parabolic bowstring girder of 107′-3″ length for the bigger spans. For every span two bowstring girders are placed on columns 36′-0″ apart and connected by cross girders over which a trough of 32′-0″ width and 12′-0″ depth rests to carry the canal discharge of 3900 cusecs with a velocity of 12 ft. per second. The girder is designed as a two hinged parabolic arch with a rise in the middle equal to 1/3rd clear span i.e. 33′-8″. The depth of the arch rib is 60″ at the springing tapering down to 36″ at the crown with a uniform width of 36″. As most of the load is uniformly distributed due to water, the bending moments induced in the arch and tie are negligible. The live load of the road induces some bending moments. These moments are shared by the tie and the arch in the ratio of their moments of inertia. Thus it is seen that the tie shares 83% and arch shares 17% of the bending moment due to live load. Nominal reinforcement has been provided for the arches. Plate IV shows the details of reinforcement of arch and tie beam. The load from cross girders and tie is transmitted to the arch by means of suspenders which are provided at 10.1′ c/c. The suspenders which act as tension members are provided with heavy reinforcement of $1\frac{3}{4}$″ diameter M.S. bars, with 6 bars on each face. The tensile strength assumed for this steel is of the order of 14000 lbs. per sq. inch. For stability of arch in lateral direction against wind pressure, two wind bracings have been provided which also incidentally serve as road beams. The concrete of the arch is of 'C' grade with a cube strength of 3000 lbs. per sq. inch.

The tie beam of bowstring arch is having a section of 36″ × 72″ with a camber of 5″ in the centre. There are nine suspenders of section 9″ × 36″ connecting the tie and arch. Plate V shows the position of arch and ties with the cross beams.

The superstructure for the shorter spans of 49′-6″ and 30′0″ are tee beams reinforced both for tension and compression. These main tee beams are connected by cross grinders over which the trough rests. There are rectangular columns provided over the top flange of the main girder to support the roadway. Plate VI shows the arrangement of these tee beams.

Trough

The trough has been made independent of the cross girders. Due to the differential temperatures it is expected that there will be relative motion between the trough and the different members of the bowstring girder. The trough consists of a slab of 7″ for a span of 10.1′. Plate VII shows the details of trough slab over the cross beams. The trough sides are designed as cantilever ends taking the stress in steel on the water side as 12000 lbs. per sq. inch and on the non water side as 18000 lbs. per sq. inch. There is a gap between the sides of girder and the trough. To make the trough move independently Shalimar Tar felt pads with a coat of bitumen in between have been provided over the cross girders. Even if the tar pads deteriorate, to take care of the frictional stresses that may come into play while there is relative movement between the trough and cross girders, two diaphragms have been provided with suitable reinforcement to stiffen the cross beams. The diaphragms are of section 45″ × 8″ and are designed assuming that the coefficient of friction between concrete and concrete as 0.30 to withstand stresses due to unequal expansion arising out of unequal variation of temperature between tie and trough. It has been a point of controversy to what length one piece of trough is to be cast. Earlier experience in other structures gave the answer to this. In spite of providing the temperature reinforcements, slabs longer than 50 feet showed signs of cracking; hence the span of R.C. slabs should be near about 50′. So instead of casting the trough in one piece over a long span of 107′-3″ it was cast in two pieces of nearly 54′-0″ each. This piece of 54′-0″ length of trough is fixed to the cross girder in the middle so that the movement of the trough is restricted to $\frac{1}{4}$th of the span. Copper U strips of 1′ wide are provided at both the ends with about $\frac{3}{4}$″ thick gap in between. This gap has been filled with sheltax pad and has been sealed off on the top with the bituminous compound. This will allow for slight movements and also provide a water tight joint. A slope of 1 in 701.4 has been provided in the trough slab to allow for the velocity to develop in the trough which is of the order of 12′ per second. To create this head to push the water through the trough and yet to keep the F.S.L. the same, a depression of 3.52′ has been provided in the entry flume. The depth of water flowing in the trough will be 10.2′ allowing a free board of 1.80′. The coefficient of rugosity for the inside surface of the trough is assumed to be 0.013. To attain the required smoothness, the trough bed and bed walls have been rubbed down with carborandum stones and a smooth surface has been presented.



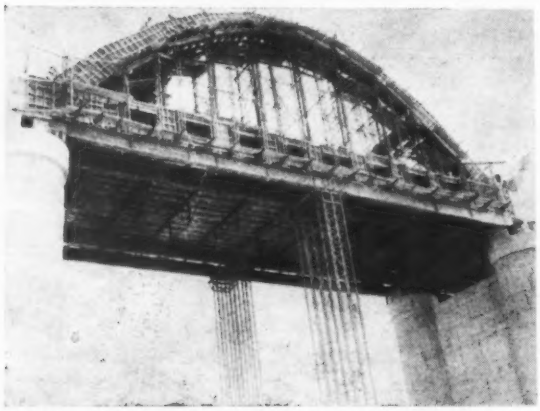
View of the aqueduct nearly complete.

Road Way

A roadway of 24′ clear has been provided at the level of the wind bracings i.e. at 15.8′ from the bed of of the trough. The slab is $8\frac{1}{4}$″ thick and rests over beams of 3′ depth supported on brackets on suspenders. Twin beams connected by diaphragms have been provided to distribute the load on either side of the suspenders. 9″ × 7″ commercial lead plates $\frac{1}{2}$″ thick have been provided at either end to take care of expansion of the beams. Care has been taken to see that the road way beams are free to move and in no way interfere with the movement of the main girder. Plate I shows the arrangements of roadway over the flumes. A layer of tarfelt has been provided to allow for the free movement of the road slab over the wind bracing. A gap of nearly 2″ has been kept at the junction at each bowstring grider. An angle of 4″ × 3″ × 3/16″ has been cast along with the slab at the junction to protect the corners. 2″ thick black top surfacing has been provided as wearing coat. The curbs are 9″ high and the railing consists of 3″ × 2″ angles fixed at every 5′-0″ with 3 G.I. pipes of $1\frac{1}{2}$″ diameter to serve as horizontals. Over the flume walls beams and slabs are provided to allow for the divergence of traffic and easy transition of the roadway from the trough to the left bank over which an inspection road runs all along the canal. The roadway over this structure has been proposed to be open to public for providing link between the two States and so it has been designed for Class 'A' loading with two lanes of traffic.

Approaches

It is for the first time that a heavy fluming has been resorted to for this type of structure. The main canal has a width of 126′-0″. The trough is only 32′-0″ wide. The fluming on the upstream side is done in a length of 188′-0″. The flume walls have been designed to have a parabolic shape and the bed has been depressed by 3.52′ to create the head for flow of water through the trough. The velocity increases from 3.14′ to 12′, per second. To withstand the heavy velocity the flume portion of the aqueduct has been lines with 8″ thick C.C. 1:2:4 slabs over 12″ × 6″ C.C. beams at 16′-0″ centres. The flumes have been filled up to a height of nearly 40′-0″ with well compacted earth. The dry density tests were conducted to ascertain the nature and the extent of compaction. At the bottom of the slab a layer of 6″ depth of sand has been provided to distribute the load properly and prevent the slab coming directly into contact with the saturated earth beneath.



Details of centering and Form work.

The bed of the canal rises at the exit flume, the length of which has been made double that of the entry flume, to minimise the loss of head due to turbulance. The exit flume is also of a parabolic shape and the bed rises by 2.98′. The total loss of head in the structure is 2.81′. The foundations of the flume walls have been taken to hard yellow soil about 10′-0″ below the N.S.L. The section of the transition wall has been kept below a depth 'd/2' as uniform as it is taken that the passive pressure comes into play and keeps the pressures on both sides of the wall the same below this depth taking 'd' as the exposed depth of the wall above the bed. The transition wall is designed as retaining wall above this level. The abutments have been taken to a depth of 6′-0″ lower than that of transition walls.

Bearings

In order to allow for the free angular and linear movements of the ends of the bowstring girders under load and also due to temperature variations, cast steel rocker and roller bearings have been provided at the supports. Originally R.C.C. rocker and roller bearings were proposed for all the spans. But the Central Water & Power Commission authorities were not in favour of adopting R.C.C. bearings for such heavy loading. Plate VIII shows the details of both cast steel rocker and roller bearings.

DESIGN CALCULATIONS FOR THE ROLLER BEARINGS

Span — 101′-0″
Width of bearing — 30″ (width of girder).
Load on one bearing — 650 tons

(1) *Rollers*

Use 4 rollers 15″ dia. and 36″ long.
Value of k, load per inch run, per inch of diameter of each roller $= \frac{659 \times 2240}{4 \times 15 \times 36} = 673$
(against 672 permissible for cast steel).

(2) *Top plate*

Size — 36″ × 36″ × 8″
Load per sq. inch of plate $= \frac{650 \times 2240}{36 \times 36} = 1125$ lbs. per sq. inch.
Projection of plate beyond line of contact = 18″.

B.M. $= \frac{1125 \times 18 \times 18}{2} = 1,82,000$ in. lbs.

Section modulus $= 1/6 \times 8^2 = 10.65$ in.^{3}

Stress in plate $= \frac{1,82,000}{10.65} = 17,100$ lbs. per sq. inch.

(3) *Saddle plate*

Size $40'' \times 36'' \times 8\frac{1}{2}''$

B.M. $= \frac{650 \times 2240}{2} \times 10 = 72,80,000$ in. lbs.

Section modulus $= \frac{36 \times 8\frac{1}{2}^2}{6} = 433$ in.^{3}.

Stress in plate $= \frac{72,80,000}{433} = 16,800$ lbs. per sq. inch.

(4) *Bottom plate*

Size $= 44'' \times 42'' \times 2\frac{3}{4}''$

Load per sq. inch $= \frac{650 \times 2240}{42 \times 44} = 790$

Section modulus $Z = 1/6 \times 2.75 = 1.26$ in.^{3}.

Stress in plate $= \frac{19.300}{1.26} = 15,300$ lbs. per sq. inch.

The cast steel bearings were supplied by M/s. Mysore Iron & Steel Works, Bhadravati.

For the shore spans of 49'-6", R.C.C. bearings have been adopted. Spiral reinforcement has been provided in the beam and the chairs, where locally heavy stresses are set up. The mix adopted is of 1:1:2 C.C. to give a cube strength of 6000 lbs. per sq. inch. A lead plate, 3/4" thick has been placed above and below the roller of 4' high to take care of rocking action. The lead plates are malleable and reduce friction and allow for the free movement of the roller. The sides of the roller have been cambered to see that the portion of the roller beyond the lead plate does not touch any portion of the supporting block or beam. The bearing take a load of 320 tons. The design calculations are as under:—

Design of R.C.C. bearings for shore span.

Span C/C = 50.50 ft.
Loading = 320 tons.
Mix of concrete high grade 1:1:2.

Ultimate compressive stress = 6000 p.s.i. after 28 days. (– R.C. Designer's Hand Book, Reynolds P.259). Adopt roller length = width of girder = 36" of length = 34". Assume 4'-0" height and 27" width for roller block. Provide contact width = 10". See sketch above. Contact area provided = $34 \times 10 = 340$ sq. inch. Sectional area of effective concrete $24 \times 36 = 864$ sq. inch.

Average stress across section $\frac{320 \times 2240}{864}$
$= 832$ lbs./sq. inch.

Contact stress $= \frac{320 \times 2240}{340} = 2110$ p.s.i.

(1) Normal permissible stress with factor of safety = 4

$P = F\ 3\sqrt{\frac{A}{a}} = \frac{6000}{4} \times 3\sqrt{\frac{864}{340}} = 2050$ p.s.i.

(2) — do — — do — F.S. 3.

$P = \frac{6000}{3}\ 3\sqrt{\frac{864}{340}} = 2730$ p.s.i.

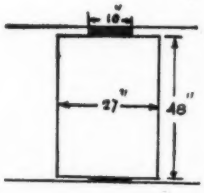
Check as per B.A. 34 French Formula (F.S. = 4)

$$P = F\left(4 - 5\sqrt{\frac{a}{A} + \frac{2a}{A}}\right)$$

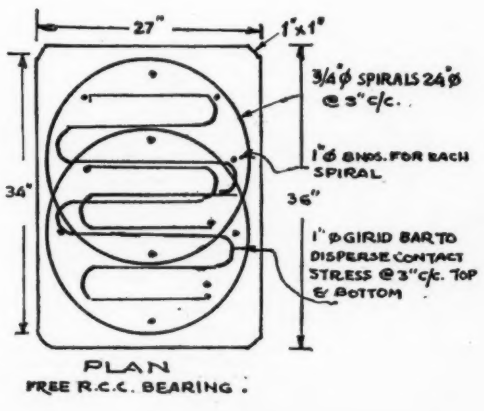
Where F = permissible compressive stress.
P = permissible direct bearing stress.
a = contact width.
A = Full width (effective).

$\frac{a}{A} = \frac{340}{864} = 0.394$

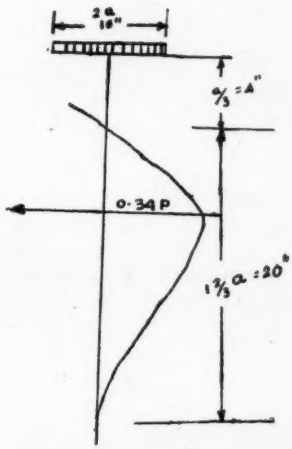
$P = \frac{6000}{4}\ 4 - 5\ \sqrt{3.94 + 2 \times 0.324}$



A
Parvati aqueduct.



B
Parvati aqueduct



C
Parvati aqueduct.

$$= \frac{6000}{4} \quad 4 - 3.14 + 0.788$$

$$= \frac{6000}{4} - 1.648 = 2470 \text{ p.s.i.}$$

Hence contact width provided is sufficient.

2. Roller as a short column

$$\text{Load/inch run} = \frac{320 \times 2240}{34} = 21{,}100 \text{ lbs}$$

Dia of helical spring = 24″.
Load/26″ run – 21,100 × 24 = 5,06,000 lbs.
Area of vertical steel = 8 × 0.785 = 6.30 sq. inch.
Value of ¾″ dia helix @ 12″ C/C and 48″ height.
= 0.442 × 24 × 11 × 5.
= 167 C. inches.
Load on short column with helical reinforcement
P = CAK + C1 × AC + 2 tb × Ab
(British standard specifications No. 114 (1948) C1.312-(iii)
Ak = Cross sectional area of concrete in the core.
tb = permissible stress in helical reinforcement
Ab = Equivalent area of helical reinforcement (in volume of helix per unit length of column).
Ac = Area of vertical steel.

$$P = \frac{6000}{4} \times \frac{24^2}{4} + 18000 \times 6.30 + 2 \times 13{,}500 \times \frac{167}{48}$$

= 6,80,000 + 1,13,500 + 94,000 = 8,87,500 lbs. safe.
Since effect of hoop steel is small, it is considered for bursting tension.

3. Bursting Tension

(Reference prestressed concrete by Y. Guyon Page 152) 2a = width of bearings = 2 × 12.00 = 24.00
2b = 1″.

$$P = \frac{P}{2a} = \frac{P}{2 \times 12}$$

$$= \frac{21.100}{24} = 880 \text{ p.s.i.}$$

Total bursting force
= 1.67 × 12 × 0.34 × 880 × 2/3
= 4000 lb/inch run of half height
Total 8000 lbs per sq. inch run.
Total bursting force as per old practice.
= 1/8 × 21,100 = 7,030 lb/inch length.
(Max. bursting stress = 0.34 × 880 = 300 p.s.i.

Lateral reinforcement (for bursting force)
Transverse steel required 24″ length.

$$= 8000 \times \frac{24}{18000} \times 10.7 \text{ sq. inch}$$

Provides 4 Nos. ¾″ dia. ft. height = 16 Nos. in. 4 ft.
∠ steel area available = 16 × 0.442 × 2
= 14.15 sq. inches.
Hence hoop steel provided is sufficient.

Fixed bearings

Provide same steel as for top and bottom blocks.

Plate IX shows the arrangement of R.C.C. fixed and free bearings.

For the 30′-0″ span, plate bearings have been provided. The plate bearings consist of 2′-0″ × 3′-0″ M.S. plates 1″ thick, lined with ¼″ thick copper plates by means of countersunk copper rivets. Graphite has been applied at the surface to ensure proper sliding of the plates due to elongation of the longitudinal beams. The loads carried by the plate bearings are of the order of 200 tons. Plate X shows the arrangement of M.S .steel plates.

CONSTRUCTION OF SUPER STRUCTURE

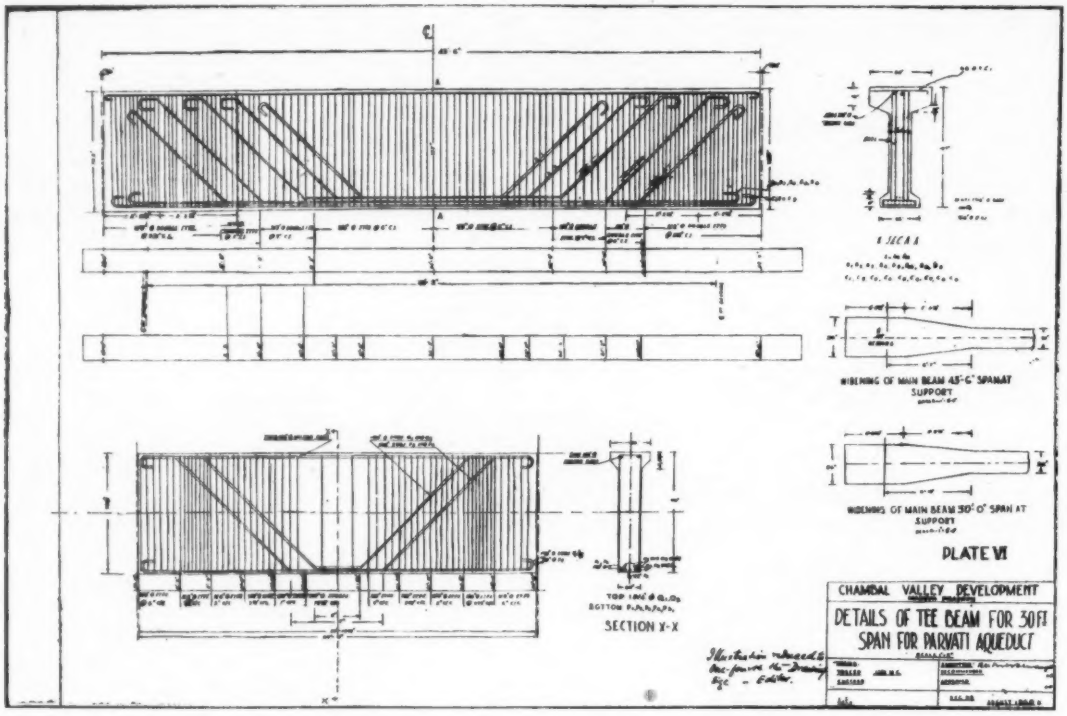
Several methods were thought out how best to support the form-work for concreting of the bowstring arch from the bed of the river for a height of nearly 82′-0″. The pool of water at the site also added to the problem. First it was thought that four steel arches could be erected to support the form-work thereby eliminating the necessity of any supports from below. But for erecting the arches the tie had to be kept without sagging so that the other members could be bolted together. This was very difficult as the span was very long and the normal section of tie required could not be kept stiff enough without a number of supports from beneath.

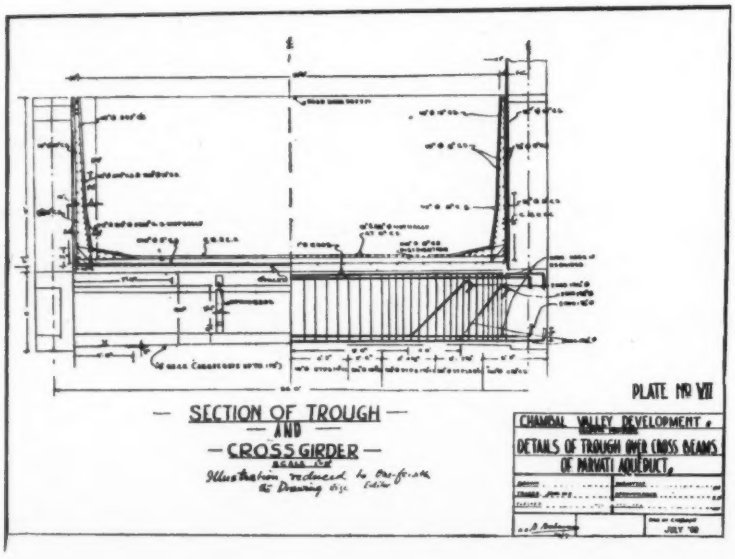
Fortunately the project had procured from the disposals some wide flange beams of 33″ × 11½″ size. This being an odd size, the properties of this section were computed. It was found that four girders were required to support the total load of the form-work and concrete coming over the entire span of 107′-3″ with a central support limiting the span of each girder to 53′-7½″. To provide a central support in the shore spans was easy. At the centre of the span on the ground below, an R.C.C. raft was constructed with two pedestals to support the two steel columns made of R.S. joists 6″ × 3″ properly braced together. Two plate girders one on either side of the chair sitting over steel chairs were supported by these two columns. To ensure proper fixity in addition to the holding down bolts, the base of the column was embedded in masonry over the pedestals. The erection of these columns and girders in position was done with the help of a derick and a winch worked by steam power.

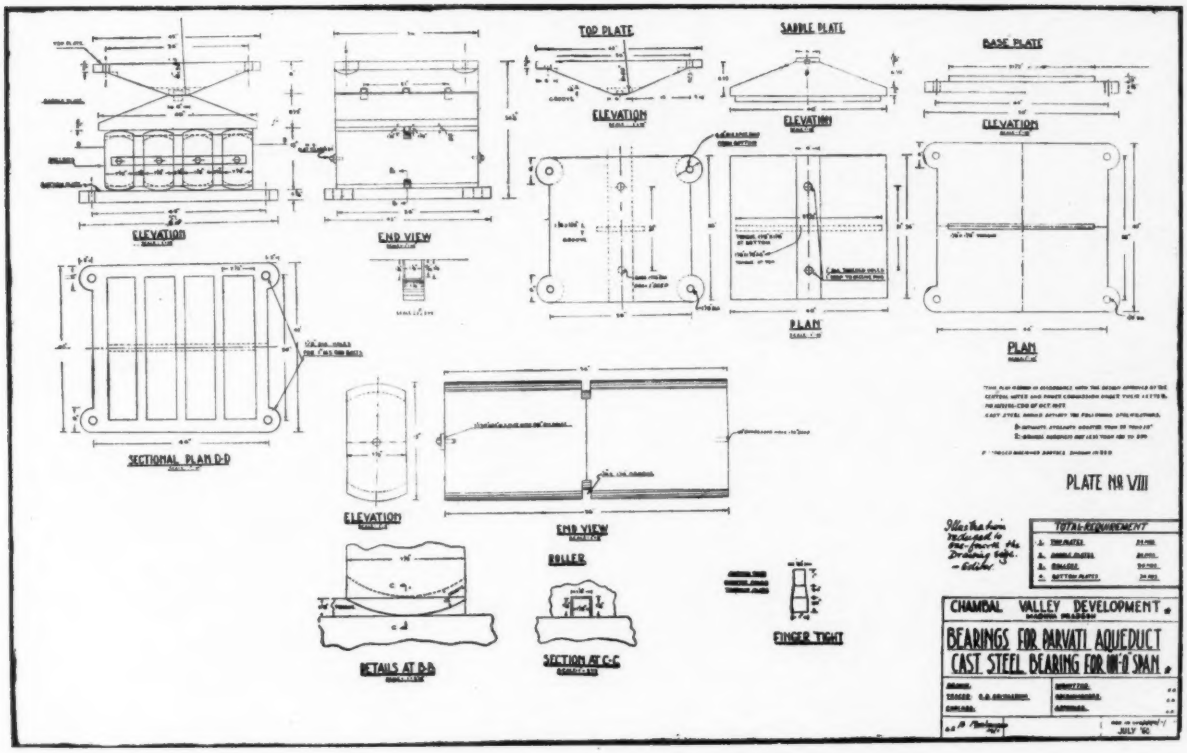
In the river spans also the same method was adopted. A cylindrical cage of about 15′-0″ diameter made of M.S. rounds properly welded together was lowered into position. Stones were packed inside and outside this cage to form a circular platform to project about 2′-0″ above the low water level. For the top 2′ or 3′ the interstices of the boulders were packed with rich cement mortar. An R.C.C. raft was laid over this platform with a pedestal to support the steel columns which in turn supported the plate girders. The bed of the river was hard enough and there was no chance of the bed yielding under load. Even then care was

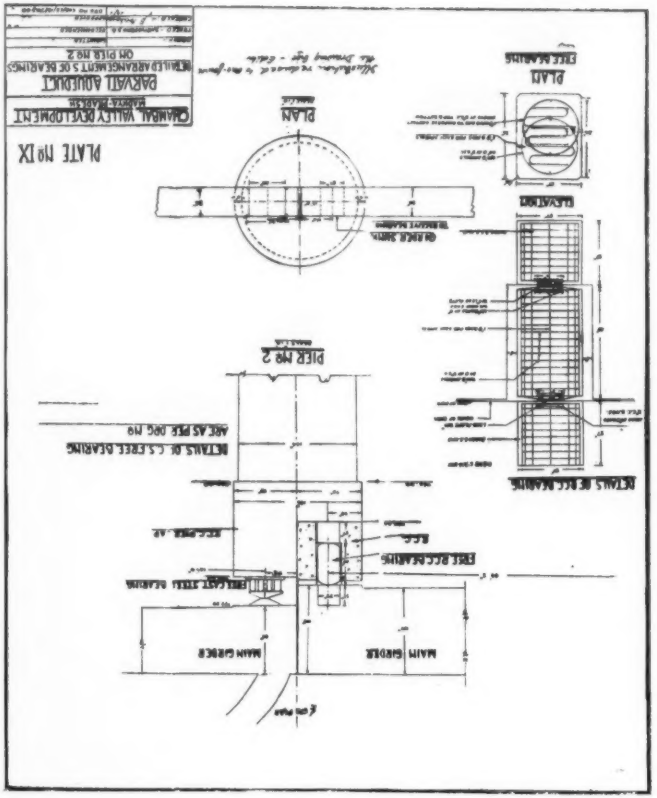
PLATE No V

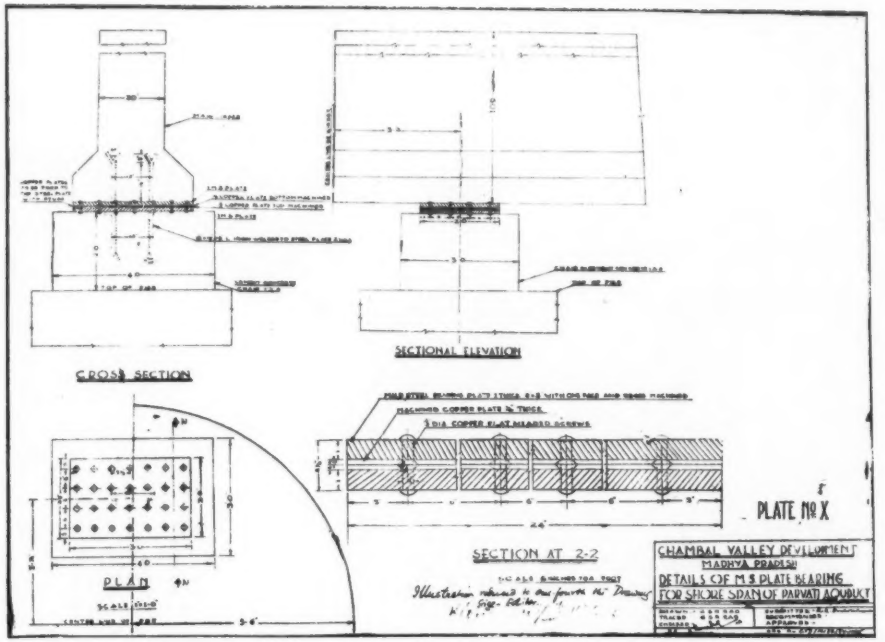
GENERAL ELEVATION OF ONE SPAN SHOWING RELATIVE POSITIONS OF CROSS-GIRDERS, SUSPENDER, BRACKETS, ROADWAY, TROUGH, ARCH ETC. WITH RESPECT TO THE


SECTION X-X
WIDENING OF MAIN BEAM 45'-0" SPAN AT SUPPORT
WIDENING OF MAIN BEAM 30'-0" SPAN AT SUPPORT
PLATE VI
CHAMBAL VALLEY DEVELOPMENT
DETAILS OF TEE BEAM FOR 30 Ft SPAN FOR PARVATI AQUEDUCT


— SECTION OF TROUGH —
— AND —
— CROSS GIRDER —
PLATE NO VII
CHAMBAL VALLEY DEVELOPMENT
DETAILS OF TROUGH OVER CROSS BEAMS OF PARVATI AQUEDUCT.


TOP PLATE
SADDLE PLATE
BASE PLATE
ELEVATION
ELEVATION
ELEVATION
ELEVATION
END VIEW
PLAN
PLAN
SECTIONAL PLAN D-D
ELEVATION
END VIEW
ROLLER
DETAILS AT D-D
SECTION AT C-C
FINGER TIGHT
PLATE No VIII
TOTAL REQUIREMENT
CHAMBAL VALLEY DEVELOPMENT
BEARINGS FOR PARVATI AQUEDUCT
CAST STEEL BEARING FOR 18'-0 SPAN
JULY '60




SECTIONAL ELEVATION
CROSS SECTION
PLAN
SECTION AT 2-2
PLATE No X
CHAMBAL VALLEY DEVELOPMENT
MADHYA PRADESH
DETAILS OF M.S PLATE BEARING
FOR SHORE SPAN OF PARVATI AQUDUCT

taken to see that the load was not more than ½ a ton over the boulder platform. The circular hoops of the cylindrical cage also ensured that the boulders do not get dislodged due to dispersion of the load.

After placing the two plate girders in position, one on either side of the chair, built up trusses made of 6″ × 3″ R.S. joists strengthened by two struts and rods designed by the strain energy method, were placed at intervals of 10.1′ to support the cross girders. A wooden platform of joists resting over these steel sections was prepared to keep the bottoms of ties and cross girders in position with the help of wedges to give the proper cambers. Columns of varying lengths to suit the profiles of the arch and made of angles 1½″ × 1½″ × ¼″ properly braced with ¾″ diameter M.S. bars were fixed to the top flange of the plate girders. These were kept in position by bolting a number of brace bars. Wooden joists of 10″ × 5″ were fixed over these columns to form a support to the arch form-work. The details of the centering and form-work to support the skeleton consisting of bowstring girders, cross girders and wind ties are clearly shown in the picture.

For the centering of the 49′-6″ span there was no problem. 15″ × 6″ R.S. joists were used to support the frame work and these were supported with the help of good bally props placed over sleepers so that the load coming over a bally was evenly distributed allowing for a maximum intensity of not more than ½ a ton per sq. ft. as the supports had to be kept on made up soil.

The banks around the flumes have been protected with stone pitching, thick, upto 2′ above W.F.L. of river. As banks are very high, turbing above the pitching is proposed to be done.

QUALITY - CONTROL

A lot of stress was laid on the quality of the work. As the mixes proposed were having a direct bearing on the cube strength developed, before the works were started, a number of mixes changing the different quantities of graded metal, and sand were tested by taking out samples to give the densest mix with particular stress to water cement ratio etc. Almost daily samples were taken to ensure the correct type of mix and strength required. Out of the three samples ordinarily taken, one was tested at the end of a week to guide the executives whether any precautions were needed to be taken as testing after 28 days did not afford the proper guidance.

As the main reinforcement was of 1¾″ diameter M.S. rounds, welding was resorted to in place of laps. About 1 per cent of the samples were cut and sent to College of Engineering laboratories, Poona and it was found that all of them gave good results.

There was a lot of discussion regarding the sequence of concreting of the arches. But in consultation with Dr. K. L. Rao, Member, Central Water & Power Commission, the following sequence was adopted: Eight days were required to complete the concreting of the skeleton which comes to about 9,000 cft. of concrete. On the first two days the two ends with a part of the arch and end cross girders were concreted. The third day the concreting of the arch was proceeded with, upto the wind bracings. During the fourth and fifth days the arches were completed in three stages. Then on the 6th, 7th and 8th days the portion of the tie along with the remaining cross girders were concreted in three stages. Thus it normally took eight complete days for concreting one skeleton of the arch. After 21 days the tie supports were released. This induced tension in the suspenders. Concreting of the suspenders upto the brackets were taken up after this. Then the road beams with the slabs were concreted. After completely filling the suspenders the centering for the trough walls was erected. In fact, concreting of the trough was the last operation to be done in a particular span. The whole of the operation took nearly 2½ months for one span but continuous operations allowed the skeleton of one span, the concreting of the road-way for the next and concreting of the trough for the third to be done in one month. Thus simultaneously work was in progress in three spans and the three items could be completed in one month thereby allowing one span to be completed in one month. Three sets of centering were used and the entire concreting of the superstructures took about 18 months to complete including the shore spans.

MATERIALS & COST

Concrete	1.332 million cft.
Cement	9,380 tons
Steel	2,075 tons
Total cost of the structure:	Rs. 89.40 lakhs.
Cost per rft.	Rs. 5,930.35
Period of completion	5 years.

CONCLUSION

Constructional technicalities of this structure are so varied and intricate and the execution of the work so taxing and troublesome that a visitor is invariably struck by what has been achieved by Indian engineers with at-site improvisations. The men engaged on the enterprise had to work under trying conditions. Their devotion to duty is beyond praise and the promise the structure holds for the future is highly noble.

TENTH ANNIVERSARY NUMBER
OF
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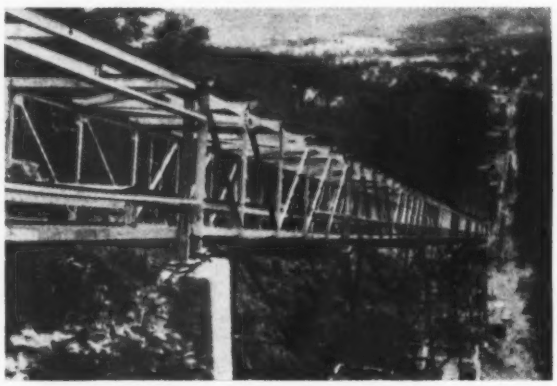

Construction view of a Hewitt-Robins downhill conveyor system for Indian Iron & Steel Company.

Part of a Hewitt-Robins conveyor and machinery installation for Bhakra Dam.

RECENT H-R INSTALLATIONS IN INDIA

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Construction Plant Machinery at Gandhi Sagar Dam

By R. A. RANGASWAMY
and L. VISWANATHAN

THE Gandhi Sagar Dam has been designed as a straight gravity dam. Construction of this dam involves about 196 lakh cft. of masonry and 60 lakh cft. of concrete. To aid the speedy execution of the work, construction plant machinery consisting of the following units, were procured under T.C.M. Aid:
(1) Aggregate manufacturing and screening plant consisting of one jaw crusher of 150 ton per hour capacity and secondary gyrosphere crushers each of 75 ton per hour capacity. (2) Sand manufacturing plant consisting of two rod mills (12′ × 6′ size) each of 30 tons per hour capacity. (3) Concrete batching and mixing plant of 60 c.yd. per hour capacity, (4) Two aerial cableways one of 10 tons and the other of 5 ton capacity. (5) Seven 50 H.P. diesel locomotives to haul the mortar and concrete from the batching plant to the aerial cableways.

While ordering these plants, it was planned to supply for constructing masonry by the day, rubble by the 10T cableway and mortar from the batching plant by the 5T cableway. In the night shift batching plant and cableway were meant for the supply of concrete. This was adopted during the working season 1956-57 and part of 1957-58. From the latter half of 1957-58 season, the cableways were utilised to transport the embedded parts of the gates and machinery in the day shift as and when required. As such the plants were exclusively utilised for concreting work in the remaining period in the day shift and the batching and mixing plants were utilised exclusively for manufacture and supply of concrete as the cableways had to shift embedded parts.

AGGREGATE MANUFACTURING PLANT

This plant consists of one apron feeder to feed the rubble to the 36″ × 24″ Lippmann Jaw Crusher. The feed to the jaw crusher is regulated by running or stopping the apron feeder as desired. The bottom opening of the jaw crusher, i.e. the distance between the swing jaw and stationary jaw plates is adjustable between 3″ to 6″ as per requirement of the size of the aggregates. The crushed aggregate is fed by a delivery chute through a 24″ conveyor (No. 1), onto a double deck vibrating screen where the aggregates are screened into different sizes. The aggregates retained on the screen are fed by delivery chutes to the two gyrosphere secondary crushers. The two secondary crushers are adjusted to reduce the feed to the desired percentage of the three sizes of aggregates used in the manufacture of concrete namely 3/16″ to $\frac{3}{4}$″, $\frac{3}{4}$″ to 1$\frac{1}{2}$″ and 1$\frac{1}{2}$″ to 3″.

If the smallest size of aggregate i.e. 3/16″ to $\frac{3}{4}$″ has to be produced more, one cone crusher is adjusted to reduce the aggregate to 1$\frac{1}{2}$″ and these are fed back by an 18″ conveyor (No. 2) to the conveyor No. 1 which again conveys the same to the double deck screen. This aggregate is fed to the other cone crusher which is adjusted to reduce most of this quantity to 3/16″ to $\frac{3}{4}$″ size. These crushings coming out of the secondary crushers and those that pass through the second screen of the double deck screen are fed to the conveyor No. 3 and conveyed to what is known as, surge pile. This surge pile formed over a tunnel contains the various sizes of aggregates mixed up.

These units are centrally controlled from one panel board. The jaw crusher is run by a 75 H.P. motor, the secondary crushers by a 60 H.P. motor, the conveyor and screen by 15 H.P. and 10 H.P. motors respectively.

The material from the surge pile is fed on to conveyor No. 4 taking off from inside the tunnel by one syntron feeder and conveyed to a triple deck screen. The quantity of feed to this screen is manipulated by controlling the vibration of the syntron feeder pan and also by varying the speed of conveyor No. 4, which is driven by a variable speed head pulley. The aggregates are screened to three different sizes in the triple deck screen and are conveyed by the conveyors Nos. 5, 6 and 7 to three stock piles. The screening that pass through the $\frac{1}{4}$″ screen are heaped up separately and are used for blending the natural sand to attain desired fineness modulus for use in the mortar for the dam masonry. This quantity is between 10 to 15 per cent of the quantity of rubble crushed. A special feature of the conveyors is that the works are of the totally enclosed type in the motor and the epicyclic gearing are contained inside the pulley. This takes. less headroom and there is no necessity of any special arrangement for protecting the motor from rains.

There are two rod mills—Marcy 12′ × 6′—each of 30 ton per hour capacity. The coarse aggregates from conveyor No. 4 are directly fed onto the conveyor No. 8 of the rod mills. There is a divider arrangement on the top of the conveyor No. 8 by which aggregates can either be fed to one rod mill or to both the

rod mills, if both are running, alternatively. The charge in the rod mills is about 29 tons consisting rods of three sizes – 1½", 2½" and 3". The rod mill is run by a 200 H.P. slipring motor. Sand is manufactured by wet grinding of the coarse aggregates.

The ground sand is delivered into a trough through which water is flowing. The flowing water, on account of a screw classifier working in it, washes away the fines, the screw itself lifting the remaining crushed sand onto a conveyor. The quantity of water that is fed on determines the quality of the sand that is obtained. About 80 to 100 gallons per minute of water for grinding and about 300 to 400 gallons per minute of water for washing is used depending on the fineness modulus of sand.

The quantity and quality of sand are controlled by the following factors: (1) the size and rate of feed of the coarse aggregate, (2) the rate of feed of sand, (3) rods—the charge, (4) quantity of water for grinding, (5) the number, size and arrangement of water jets and the jet pressure, and (6) the depth of overflow over the weir.

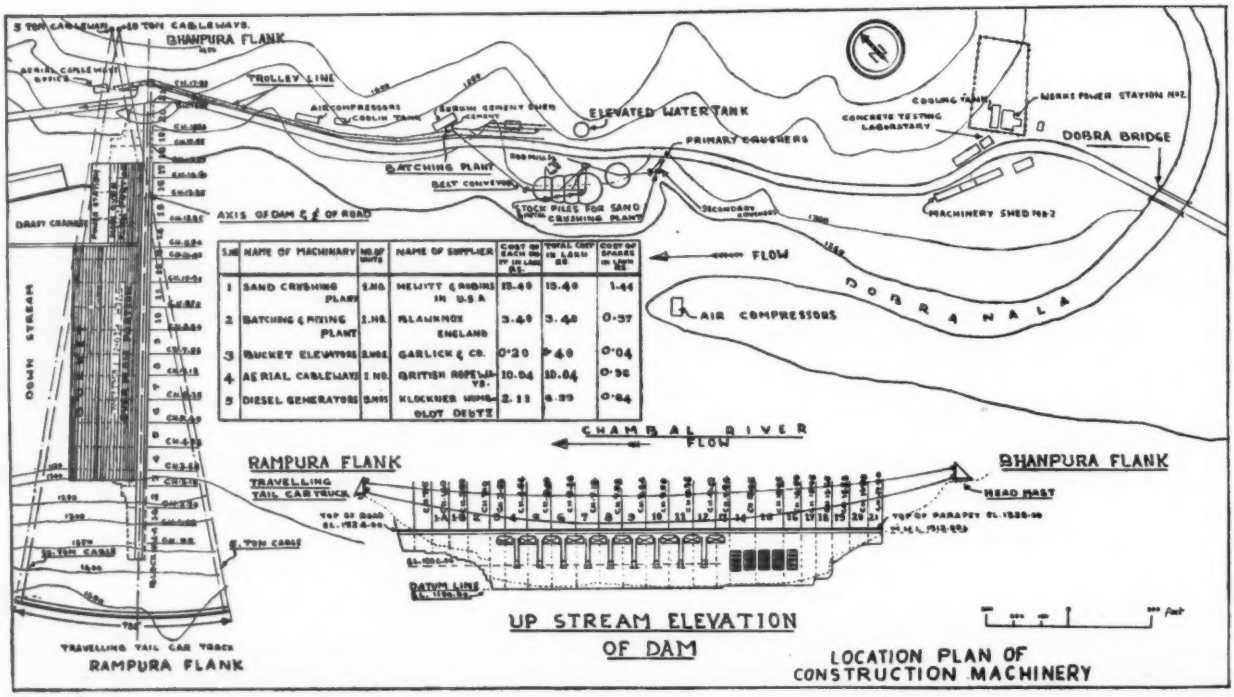
The entire aggregate manufacturing plant, crushers, screws and conveyors are electrically interlocked. If any motor power unit ceases to function all units on the inflow side automatically stop. This arrangement prevents serious consequences from motor failures or operation mistakes.

The three sizes of coarse aggregate and sand are stocked over a reclaiming tunnel 196′ long. At a time one size of aggregate is fed onto conveyor No. 10 operating inside the tunnel which thereafter feeds conveyor No. 12. This conveyor No. 12 is 384′ long and has 100′ rise and conveys the material to the rotating feeds chute on the top of the batching plant which feeds the material to the respective storage bins. The aggregates are fed to conveyor No. 10 by a manually operated gate and the sand by two syntron feeders. These syntron feeders, conveyor No. 10 and conveyor No. 12 are controlled from the batching plant operating room. The driving head pulley of all the conveyors are of the totally enclosed type, the motor and the epicyclic gear system completely enclosed, inside the pulley drum.

There are two stone quarries one just opposite the crushing plant and one about 1600 feet from the plant just near the site of the dam. The rubble is loaded by 1½ c.yd. Ruston Bucyrus or Lorain shovel on to 6.25 cyd. gear tipping Koehring dumptor. The dumptors top the rubble on to the apron feeder.

The plant is generally run for two shifts of 8 hours each; occasionally it is run for the 3rd shift also depending on the off-take of the aggregate.

A special experience in this project is the quick wearing out of the corrugation of jaw plates. The rock is of a very abrasive quality. The corrugation of one stationary jaw plate completely wears out after 10 hours of the operation and those of the swing jaw plates after 100 hours of operation. This resulted in a serious set back initially, as one could not be expec-



S.No	NAME OF MACHINARY	NO. OF UNITS	NAME OF SUPPLIER	COST OF EACH UNIT IN LAKH Rs.	TOTAL COST IN LAKH Rs	COST OF SPARES IN LAKH Rs
1	SAND CRUSHING PLANT	2 NOS	MEWITT & ROBINS IN U.S.A	15.40	15.40	1.44
2	BATCHING & MIXING PLANT	2 NOS	BLAWKNOX ENGLAND	3.40	3.40	0.37
3	BUCKET ELEVATORS	2 NOS	GARLICK & CO.	0.20	0.40	0.04
4	AERIAL CABLEWAYS	1 NO.	BRITISH ROPEWAYS LTD.	10.04	10.04	0.36
5	DIESEL GENERATORS	3 NOS	KLOCKNER MOEHLOT DEUTZ	2.11	6.33	0.84

View of Batching and Mixing Plant.

ted to stock a large number of jaw plates. This initial difficulty was overcome by developing an indigenous method of building up the jaw plates. On every 5 hours of operation of the plant, the stationary jaw plate has to be inverted and on every 10 hours of operation the plate is replaced. The swing jaw plate is inverted every 50 hours of operation and changed every 100 hours of operation. The inverting operation for both the type of plates takes about 45 minutes and the changing operation about 1½ hours. The plant has to be stopped during these operations.

Building up of Stationary Jaw Plates

An ingeneous method for the building up of the worn out jaw plates was evolved by the project engineers. Instead of using a lot of electrodes in building up the jaw to the required profile fourteen 22″ long 1½″ octogonal chisel steel rods are welded to each half of the stationary jaw plates with 6 or 8 sws. manganese blended electrodes. The performance of the jaw plates with this type of welding was found to be similar to that of the original ones. One jaw plate is built up completely in 24 hours.

The swing jaw plate also is clamped the same way as the stationary jaw plates. The plate corrugations are built up by depositing the weld metal. The same manganese electrodes are used for this purpose, also. Due to huge amount of welding involved, the plate gets heated up and so to avoid cracks due to uneven heating the welding is stopped for ½ hour after every half an hour of welding. This building work takes about 15 days.

With the method of protecting the jaws as described above, the total life of one swing jaw plate was increased to 1000 hours and stationary jaw plates to 200 hours compared to the original figures of 100 and 10 hours. The cost of building up the plates for every ton of the rubble crushed, has worked to Rs. 0.60 on an average.

Cost Details

The cost of feeding the rubble to the apron feeder with the shovel and dumptor works out to Rs. 3.25 per ton. The cost of crushing and conveying the aggregates to the batching plant is Rs. 11.75 per ton. The cost of manufacture of sands Rs. 13.75 per ton. The crushing plant has worked for 5700 hours and crushed 2.4 lakh tons of rubble. The total cost of this plant is Rs. 14 lakhs. As there is no direct agent in India for this plant and its components, the project experienced quite a bit of difficulty in procuring spares in time. However the project engineers saw to the uninterrupted working of the plant by manufacturing the required parts locally in the workshop.

CONCRETE BATCHING AND MIXING PLANT

This semi-automatic concrete batching and mixing plant was supplied by M/s. Blaw Knox Ltd., London. The cost of the plant is Rs. 3.80 lakhs.

General Description

The plant consist of one 35 feet diameter single ring storage bin which is divided into four equal compartments for storing aggregates, each with a capacity of 100 cyds. In addition a central circular water proof compartment is provided, divided into two sections, giving a cement storage of 62 tons and surkhi storage of 14 tons. A manually operated swivelling turn head discharges the aggregate to the required compartment. Two aggregate weigh hoppers and one cement and surkhi weigh hoppers are dispersed under the opening of the common storage bin. The capacity of the hoppers are such as to give a wide range of mixes. Interlock limit switches are fitted to the aggregate and the cement weigh hoppers and are arranged so that the discharge gates of the hoppers cannot be opened while weighing is taking place. Each weigh hopper is suspended on rocker arms with knife edge bearings, to allow freedom and alignment and is coupled by means of levers and bearings to an 18″ diameter dial indicator. The dial mechanism is of the springless pendulum type.

Shovel and Dumper at work.

Control Panel

Weighing of materials is semi-automatic in conjunction with the weight dials for aggregate cement and surkhi. For feeding aggregates and for cement weighing appropriate switch button marked 'Fast' is depressed until a predetermined underweight is attained and then released. Then the switch marked 'slow' is pressed until correct weighing is reached. The hopper is now ready for discharge. All hoppers have independent discharge and discharge is effected by depressing the button switch marked 'open' and the gate remains open until 'close' buttion is pressed. Two push buttons are installed on the panel for the water weigher, one to open and the other to close the valve.

The three mixers of 1 cyd. capacity each rotating at 16 R.P.M. run by 15 H.P. motors, are fed from the weigh hoppers through a rotating chute which will stop automatically opposite the mixer selected by the chute control switch and its position will be indicated by lamps on the control panel. When the rotating chute has stopped opposite the selected mixer, the gap between the mixer and the mouth of the chute is closed by a telescopic spout on pressing button marked (down). When the weight hoppers are empty and their gates are closed pressure on the 'up' button will retract the spout and allow the rotating. The position of the spout is indicated by lights on the control board.

The mixer can be raised or lowered to the discharge position by pressing the appropriate button. The spout mentioned above cannot be lowered unless the mixer is in the revised position and the mixer cannot be lowered if the spout is down. When the mixer has been charged it cannot be lowered or discharged until the correct mixing time adjusted on the back timer has elapsed. During the mixing period a red lamp glows on the control panel.

Water measuring tank

The water measuring tank consists of a vertical type measuring tank which is operated by a pneumatic ram remotely controlled from the panel. The water is measured volumetrically by means of a vertical adjustable syphon, which can be set accurately by means of a guage and graduated indicator. The indicator is graduated in pound and gallons to measure a quantity from 10 to 40 gallons. On opening the 3″-3 way valve so as to allow discharge, the inlet valve is closed and the predetermined quantity of water is discharged, and on closing the discharge valve the tank is automatically refilled.

The concrete mix is discharged from the mixers to a collecting hopper of 9 cyds. capacity. The discharge gates are of the inter-locking clam shell type, operated by pneumatic cams controlled by button at the ground platform.

All the operations of this plant are controlled by electropneumatic valves operated at 250 A.C. These

Swing Jaw Plate Welding.

Stationary Jaw Plate Welding.

valves are switched 'on' or 'off' from the control board. They in turn pass the compressed air (pressure about 90 lb. per square inch) to operate the pneumatic rams which open or close the gates, tip or raise the mixers.

Bucket elevators

There are two bucket elevators 105′ high each to elevate cement and surkhi to the respective storage bins. These were supplied by M/s. Garlic & Co., Bombay and were purchased by the project at a cost of Rs. 45,000. The cement and surkhi are stored in bags in a shed adjacent to the batching plant. The bucket elevators are loaded at the bottom by labour. The cement elevator elevates 20 tons per hour and the surkhi elevator 10 tons per hour and these elevators are run by 12.5 H.P. motors at 32 R.P.M. through a worm reduction gear box.

The batching and mixing plants runs for 20 hours in a day normally with 2 hours of maintenance after day shift and night shift. On Sundays the day shift is completely utilised for weekly maintenance and minor repairs if any. The plant has produced 61 lakhs cft. of concrete and 60,000 cft. of mortar.

AERIAL CABLEWAYS

The aerial cableways were procured and installed to facilitate the construction work of the dam especially in the latter stages involving greater quantities of concrete and higher lifts. The plant consists of two units, one of 5 ton capacity and the other 10 tons, the 5 tons cableway being situated on the downstream side of the 10 tons cableway. These plants were procured from United States under T.C.M. aid, The plant was erected under the supervision of the suppliers by the project personnel and is manned by locally trained crew.

The plant consists of a common fixed headmast located on the right flank of the river where the driving winches and control gear are situated. The hauling carriage moves on a traction cable of 9″ and 6¼″ circumference (10 ton and 5 ton respectively) steel half locked coil cables, the other end being secured onto the tailmast capable of moving on a track built in an arc of a circle of 2,150′ radius, 600 feet long, the

movement being controlled from the operator's cabin on the headmast.

The special feature of this cableway is the travel-lift arrangement for quick operation. The haul could be lowered simultaneously with the haulage outwards and the reverse operation while travelling in. This reduces the time required for lowering and hoisting.

FEATURES OF THE PLANT

Sl. No.	Particulars:	Upstream Unit:	Downstream Unit:
1	2	3	4
1.	Load carrying capacity at the hook	10 tons	5 tons
2.	Span	2150 ft.	2150 ft.
3.	Maximum traversing speed	1200 ft. per min	1200 ft. per min.
4.	Maximum normal hoisting or lowering speed.	200 ft. p.m.	200 ft. p.m.
5.	Maximum hoisting or lowering speed with fast gear engaged	400 ft. p.m.	400 ft. p.m.
6.	Tail car travel speed	25 ft. p.m.	25 ft. p.m.
7.	Details of motors fitted with winches.	240 H. P. 3 phase slip ring motor with one hour rating at 585 RPM.	135 H.P. 3 phase slipring motor with one hour rating at 583 RPM.
8.	Rotor slip resistance for six speeds:	3.54 Ω per phase.	1.775 Ω per phase.
9.	Details of travel motors:	2 Nos. 15 H.P. each slipring type.	1 No. 20 H.P. slipring type.
10.	Load at headmast end of track rope when full load is lifted	140 tons	69 tons.
11.	Common headmast structure designed for	700 tons	700 tons.
12.	Common tailcar track length	760 ft.	760 ft.
13.	Air Compressors for pneumatic operation of clutches and brakes	2 Nos. of 10 H.P. motors.	2 Nos. of 10 H.P. motors.
14.	Operating air pressure.	75 p.s.i. to 95 p.s.i.	75 p.s.i. to 95 p.s.i.

Maintenance and Operation

Since the plants were initially designed for supplying rubble and mortar during the day shift for masonry and concrete during the night shift, the cableways with different capacities were ordered. The 5 ton cableway was intended to convey mortar and the 10 ton to convey rubble for masonry during the day shift. To facilitate this, the 10 ton cableway was installed on the upstream and 5 ton on the downstrem side.

COST DETAILS

	Rs.
Cost of the plant	11,00,000
Cost of erection including civil works	4,00,000
Average cost for hauling 100 cft. of concrete	18.00
Cost per ton of hauling	2.70

The electrical energy required for running these construction plants and lighting the dam was being supplied by a 2,500 k.W. diesel power station. Five units of 500 k.W. each were installed in the station, three of them being supplied under T.C.M. aid and the other two procured locally. The first three sets were erected under the supervision of an erector of the firm, but the other two sets were erected and commissioned departmentally by persons trained in the project. The fuel oil consumption per break horse-power for the entire working period of the power station has been maintained at a very low value of 0.39 to 0.41 pounds. It will be of interest to mention here that the cost of consumables including diesel and lubricating oil per k.w.h—has worked out to Rs. 0.11 and that on establishment to Rs. 0.008.

The thermal efficiency of the station has worked out to a high value of 34% in spite of the fact that the station is subjected to intermittent peak loads due to the construction plants. Thus this power house could be safely compared to any of the efficiently maintained power houses in India.

SOME INTERESTING STATISTICS

1. Rate of generation of diesel power excluding depreciation Rs. 0.12 per k.W.h.
2. Cost of crushed aggregate at the bin of batching plant Rs. 12.00 per ton.
3. Cost of building and reclaiming jaw plates of primary crusher Rs. 0.60 per ton.
4. Cost of hauling concrete to the cableways Rs. 4.60 per 100 cft.
5. Hourly efficiency of batching plant 74%.
6. Hourly efficiency of 5 ton cableways 96%.

(Continued from page 78)

ROLE OF MATERIALS TESTING LABORATORY.....

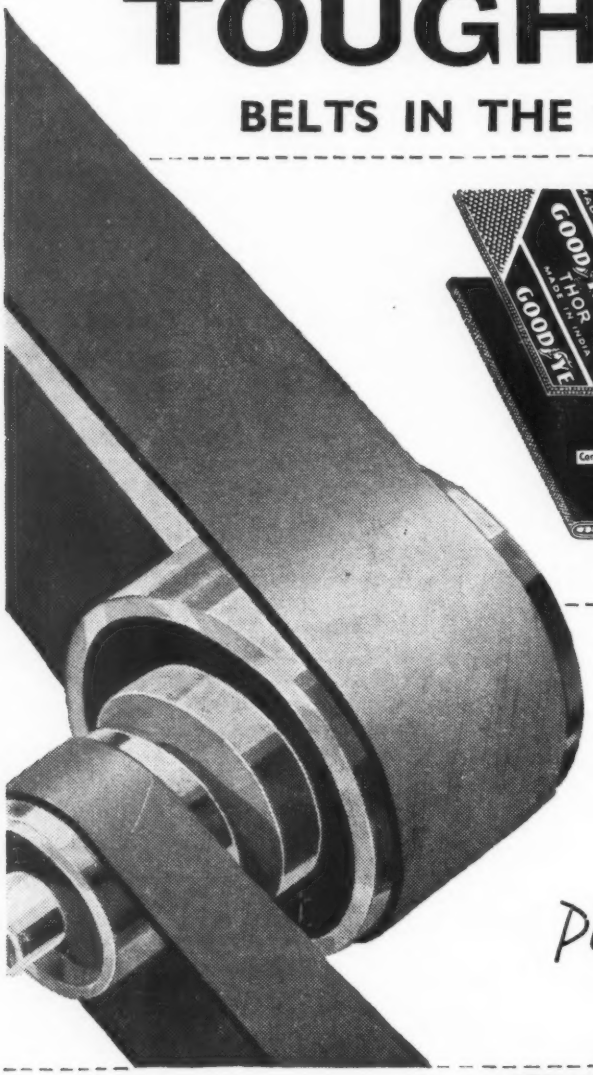
conducted. A notable feature is a fog room maintained at 95 to 100 per cent humidity and at fairly constant temperature for curing the specimens to be tested upto the age of 28 days.

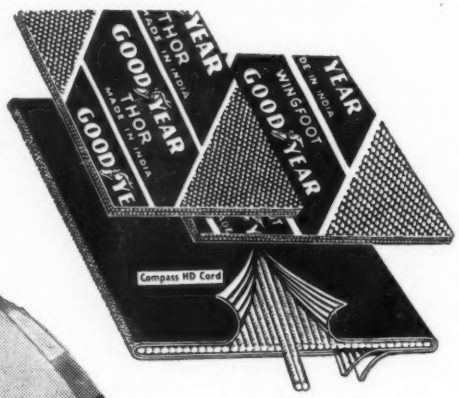
ACKNOWLEDGEMENT

I am deeply indebted to Shri A. K. Char, Chief Engineer, for taking personal interest in the guiding establishment of the laboratory, and investigations and tests carried in the laboratory. The help rendered by all the research and engineering assistants in carrying out this work is gratefully acknowledged.

TOUGHEST

BELTS IN THE WORLD





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THE GREATEST NAME IN RUBBER

Stores Organisation in Chambal Hydel Scheme (Gandhi Sagar Dam)

By V. K. MENON

THE Stores Organisation in any big project or undertaking is, contrary to the common belief, of utmost importance for the successful execution of the work and its completion within the stipulated time. It is seldom realized that equipment and materials which form the major part of the expenditure on any project has to be procured, issued and accounted for by the purchase and Stores Organisation from the very beginning and thereby the Stores Organisation has to play a very vital role in the successful execution of the project. Many of the difficulties experienced in the day-to-day working of the project could be traced to a lack of proper planning in acquisition of materials and the absence of a well-organized stores with experienced personnel. Government have laid down various rules to regulate the purchase, custody, issue and accounting of stores with a view that there should be no undue wastage of public money. Unless there is a well-organised stores functioning with adequate and efficient staff well versed in rules and procedures from the very inception of a project, there is bound to be confusion resulting in unnecessary delays, irregularities and uneconomical execution of work leading to public criticism. In a huge public undertaking involving enormous sums of money any slight irregularity, even if committed in good faith, is liable to come to adverse notice. Stores and transactions therein are liable to attract undue attention and it is all the more necessary that stores transaction and accounts are maintained in perfect order.

A Stores Organisation is a specialized agency, its activities in a huge project of this nature extending over a wide field such as purchases, transport, storage, issues, stock control, maintenance of statistics and accounts and so on. All these exacting functions require considerable knowledge as well as training before they can be efficiently and economically performed. By establishing a Central Stores and Purchase Organisation, the field officers are relieved of the worries regarding procurement of materials and also of maintaining cumbersome stores accounts and thus are free to concentrate on their works. A Stores Organisation should therefore get the priority it deserves and this fact is coming to be realized more and more with the execution of several projects in the country.

The growth of the Stores Organisation in Chambal has followed almost the same pattern as in other big projects in the country. It has had a very modest beginning there being no separate organisation for stores in the earlier stages. It started with the acquisition of defence disposal stores worth a few lakhs of rupees sometimes in 1948-49 which was received and kept in a small shed in-charge of a senior grade Overseer attached to the Mechanical Subdivision. The civil engineers had a similar small stores of their own. Dearth of necessary and qualified staff and storage facilities and other difficulties soon found the stores in great confusion and arrears in accounts. The necessity for having a separate stores organisation was keenly felt and in 1950, the Central Stores was formed as a part of a Subdivision. The Stores was later on upgraded to an independent Subdivision in the year 1953 in-charge of an assistant engineer and thus it can be said that the nucleus of the Central Stores Organisation came into existence. The project was in its infancy during this period and with the gradual increase in work, the necessity to strengthen the Stores still further was keenly felt and spasmodic attempts to improve it was made.

In the year 1957, the tempo of work on the dam increased enormously and the Electrical Circle also started functioning. Many new Divisions were created and the flow of electrical machinery such as generator and turbine parts and other equipments started and it was found necessary to once again reorganize the Stores bringing it to the level of a Division, and strengthening it with additional staff and storage facilities.

The Stores Organisation now consists of a Stores Officer with the rank and status of an executive engineer, four assistant engineers and other subordinate staff. A chart showing the set-up of the Central Stores is Appendix 'A'.

The Central Stores Organisation is divided into various branches, viz. (1) The Purchase Section; (2) The Receipt and Issue Section including Sub-Stores at dam site; (3) The Accounts Section; (4) The General Section; and (5) The Rail Head Office.

PURCHASE SECTION

One of the peculiar features of this project is that, unlike in other projects where there are separate purchase organisation with purchase officers, the stores officer is also the purchase officer. This arrangement

Above : Central Stores in early stages & below : Central Stores at present.

has proved advantageous in that he is in a better position to co-ordinate the work of purchases and stores, according to requirement of Divisions. If the two were separate, lot of difficulty in payment of bills would have also arisen. Moreover this arrangement enables a more realistic purchase programme by virtue of his control over the stores as well. Economy is another important feature of this arrangement. But it has its drawbacks in that it becomes too onerous and at times difficult.

The Purchase Section is a very important part of the Central Stores Organisation, it being the Central Purchase Organisation for the project. The annual purchases during the last 3 to 4 years have varied from 2 to 2½ crores per year and stores worth about 9 crores have been purchased during the past seven years. This Section is in-charge of an assistant engineer (Mech) with two purchase supervisors and several purchase assistants. Requisition for materials are received in the Purchase Section, scrutinized and after checking up the stock position, procurement action is taken. This is done by calling quotations or tenders in cases where the purchases exceed Rs. 5,000/-. Where particular stores are on Rate Contract of D.G.S. & D. they are obtained by placing orders or indents with them. On receipt of quotations or tenders which are opened by the stores officer personally, comparative statements are prepared, quality, prices, etc., verified by the assistant engineer and checked by the divisional accountant before the purchase is finally approved. Where it is felt that further technical opinion is required, the case is passed onto the indentor before the order is placed.

During the last 4 years, when the tempo of work was at its peak, the Purchase Section issued 2,773 quotations, 170 tenders and 4,607 purchase orders. During the past 6 years, the following quantities of important stores have been purchased.

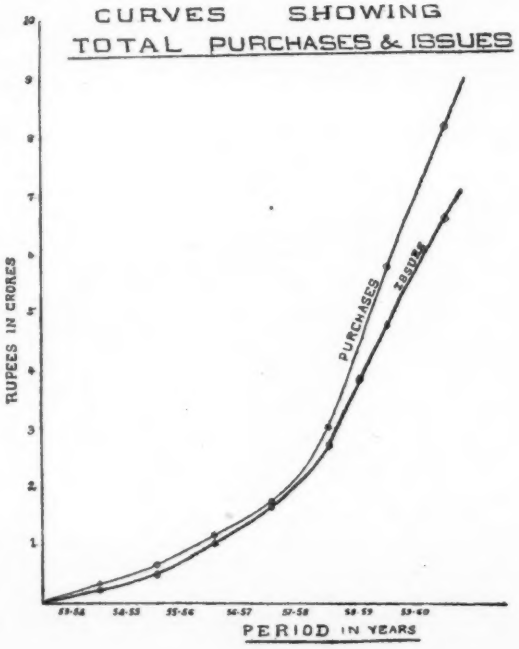
Material.	*Total.*
Cement	1,54,733 tons.
Steel	8,047 tons.
High speed diesel & light diesel Oil	24,26,838 gallons.
Petrol	2,05,419 gallons.

The Central Stores has endeavoured to assess the requirements of the several field officers including the principal medical officer by collecting the information periodically to arrange purchase. In cases of emergency, the requirements are processed on priority basis to ensure immediate supply.

The Stores Organisation has had to face much difficulty in its purchases, made through D.G.S. & D. In a project of this magnitude work is executed at a rapid pace and materials are required at very short notice the procedure of purchase through D.G.S. & D. is not, therefore suitable, as this takes more time. On many occasions we had to ignore the Rate Contract and obtain materials from the open market.

It is, therefore, felt that in huge projects like this, relaxation in the procedure for purchases through D.G.S. & D. in emergent cases is necessary.

Difficulties have also been felt in the quick acquisition of materials for want of adequate financial powers. It is felt that the project authorities should have more financial powers than at present. Even the chief engineer of the project is not authorised to make ad-



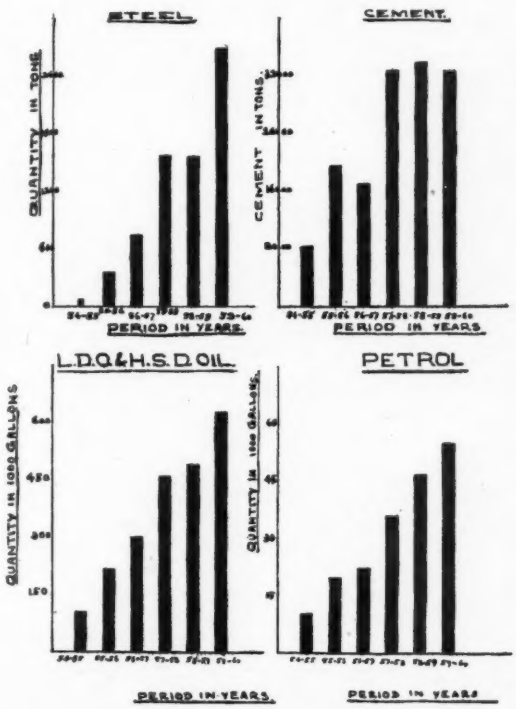
vance payment even of a rupee and every time Government has to be approached.

Planning of requirements sufficiently in advance is the key to success of any purchase organisation. Prior intimation of requirement would enable the purchase section to obtain timely supplies economically. It also gives the purchase officer sufficient bargaining power. It is not necessary that all materials are available ex-stock, as ex-stock prices are more, and even double at times. Therefore with the utmost co-operation of the indenting Divisions, the purchase and stores organisation of this project was able to work successfully and arrange supply of materials in time as they placed their requirements sufficiently in advance.

The stores officer is also entirely responsible for payment for the materials received but difficulty is experienced in this regard due to the rigid adherence to rules which do not fit in with the tempo of the project works. Thus the position of the stores and purchase officer becomes rather difficult. While, on the one hand, he is pressed for urgent procurement of materials, which he does, on the other he has to face unnecessary criticism by the suppliers for non-payment in time, for which he is helpless. Relaxation of the rules to get rid of vexatious procedure and overcome this difficulty is absolutely essential.

RAIL HEAD OFFICE

This is one of a very few major projects in the country which has no railway siding, the nearest railway station being at a distance of 32 miles from the dam site. Since Gandhi Sagar Dam is not connected by rail, all the stores from the biggest parts like rotor to the smallest parts like nuts and pins have to be received at Jhalawar Road railway station and transported to the Central Stores at dam site in trucks. Materials are received at the railway station and their proper unloading and transiport, etc., are arranged by the junior engineer at rail head and his staff through the carting contractors. This work required great care and precaution in order to avoid heavy accumulation of stores at Jhalawar Road railway station, where there are no proper facilities for storing materials, as also to avoid incurring heavy demurrage and wharfage. Similarly, arrangements have to be made at the receiving end to see to the proper receipt, verification and accounting of materials.



The project had ordered special equipment for installation at Gandhi Sagar Power Station as also transmission line materials and sub-station equipment which were received at various destinations. Their accounting is also done by the Central Stores and the Central Stores has to keep a watch of their receipts there. Besides these, huge parts pertaining to sluice, crest, emergency and penstock gates had been received. Even in case of machinery the packages received were of unusual dimensions; the length extending to 45 feet and weighing up to 35 tons. It was a problem to handle them and cart them to site without any mishap with the equipment available at the project. However, it is a matter of great satisfaction that the project staff rose to the occasion and the handling and carting was done without any damage.

Storage of special machinery like stators, etc. was another problem to be tackled. The suppliers desired that they should be stored under certain regulated conditions such as control of temperature, etc. so that their insulation may not get damaged. Due care had to be taken to store them properly till they were issued for erection.

Special arrangements had also to be made for carting of cement and light diesel oil. About two thousand gallons of light diesel oil was required per day for the Works' Power House on which the entire project depends. Any delay in supply would result in the complete breakdown of life in this project. Therefore special arrangements had to be made to instal a depot at Jhalawar Road railway station with a storage capacity of forty thousand gallons of diesel oil from where it is carted daily to the dam site. Similarly during the peak period of the project the consumption of cement is very heavy and the same is carted throughout day and night except for a short break. Special arrangements for supply of petrol to the fleet of vehicles at the project had also to be made with the oil companies who have installed pumps run by their dealers who supply petrol as and when required.

RECEIPT & ISSUES

One assistant engineer in-charge of the Receipts and Issues Section at the Main Stores with several junior engineers and other executive subordinates under him. Similarly, another assistant engineer is in-charge of receipts and issues at the Sub-Stores at dam site. As soon as materials are received they are verified by the executive subordinates and measurements recorded after which they are handed over to the store keepers who take them on their receipt books and bin cards. The bills are thereafter certified and passed on to Accounts Section for payment. Measurement books have been replaced by stores receipt books and this has enabled quicker payment of bills.

After verification of materials, the issue rates are also fixed by this Section, and finally approved by the stores officer. The issue rates are arrived at by taking into account the cost of materials plus all incidental charges such as insurance, freight, carting charges, D.G.S. & D. inspection charges, etc. Storage charges ranging from 1% to 3% is charged to the works on the stores issued to cover expenditure on custody and handling by the stores.

Issue of stores are made on indents as per stores rules. Materials are issued only against works, thus relieving the field officer from the necessity of maintaining stores accounts. This also enables direct booking of expenditure on several works at a time by the Stores and facilitates central accounting. It would be interesting to note that materials can be issued from Stores only according to requirement of works and so indents for stores can be made for the actual requirement only.

One difficulty that has been experienced is that no staff has been provided for following up the purchases from various markets. Unlike other projects, there were, no Liaison Officers posted at important markets and it became necessary to send out officers attached to the Receipt Section for chasing the pending orders. This upsets the normal work as also creates delay in acquisition and supply of materials to the consuming Divisions.

The Receipt Section is also responsible for preferring claims on railway and insurance companies, each executive subordinate in-charge of receipts looking after the claims pertaining to him. It can, however, be said that considering the volume of stores handled, the number of claims is not very much, but the railways take a long time in settlement of the same, though they are pursued vigorously.

ACCOUNTS

It is a well-known fact that the accounts of the stores in any project have a direct bearing on the accounts of the project. It therefore becomes all the more necessary to keep correct accounts in Stores. In the earlier stages, the P. W. System of Stores Accounting was in vogue. When the Central Stores was formed separately in 1953, revised Stores Rules were introduced and Bin Cards, Store Receipt Books, Revised Indent Forms, Gate Passes and Stores Ledgers were brought into use. The introduction of this new system resulted in maintenance of accurate accounts of the stores both in respect of quantity and value. Under this system, materials borne on the stock accounts are accounted for in the Bin Cards which incorporate the daily receipts, issues and balances. The Stores Ledgers also take cognizance of these transactions forthwith, as they are also posted side by side on the same day. This new system, therefore, enables the Stores authorities to have an idea of the up-to-date stock position of the materials held in Stores. As the Stores Rules envisage issue of materials against works only, it enables booking of expenditure on works in a consolidated form unlike the orthodox P.W.D. Rules with the system of Inter-Divisional Transfers. This can, therefore, be called a refinement in the system of Store Accounts. With the sanction of additional staff in 1957 the accounts section of the Stores has been thoroughly reorganized in the light of the revised Stores Rules and various branches for payments, adjustments, Stores accounts and ledger, cash, miscellaneous and establishment matters established. Reconciliation of value and quality accounts has also been attempted satisfactorily. A post of Commercial Accounts has been sanctioned for this purpose.

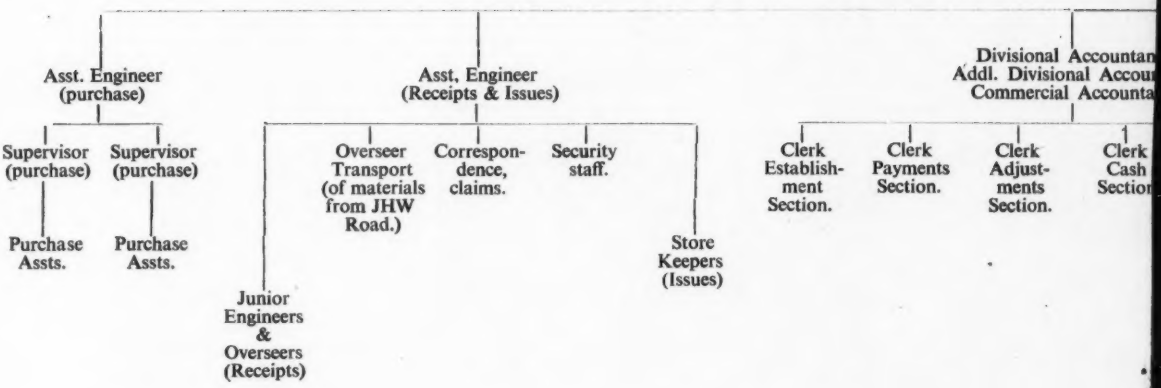
SECURITY

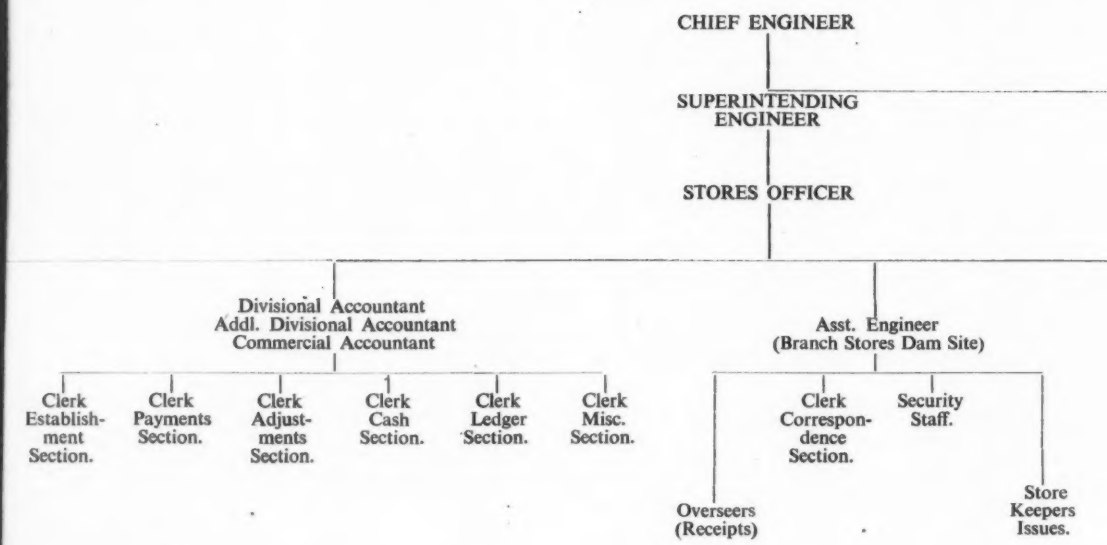
Safety of materials held by the Stores is of utmost importance and for this purpose, a very efficient security staff is maintained. Apart from strict check of men and materials passing out of the Stores at the gates, watch of the store yards and godowns is maintained round the clock. Information regarding materials passing out of the stores is separately maintained at the gate to ensure availability of independent data for materials leaving Stores and serves as a double check in location of errors, if any, at a later date. Sufficient number of chowkidars have been appointed at the Stores and at the railway yard. Telltale clocks have been provided and this ensures that the chowkidars perform their duties properly.

PHYSICAL VERIFICATION OF STOCK

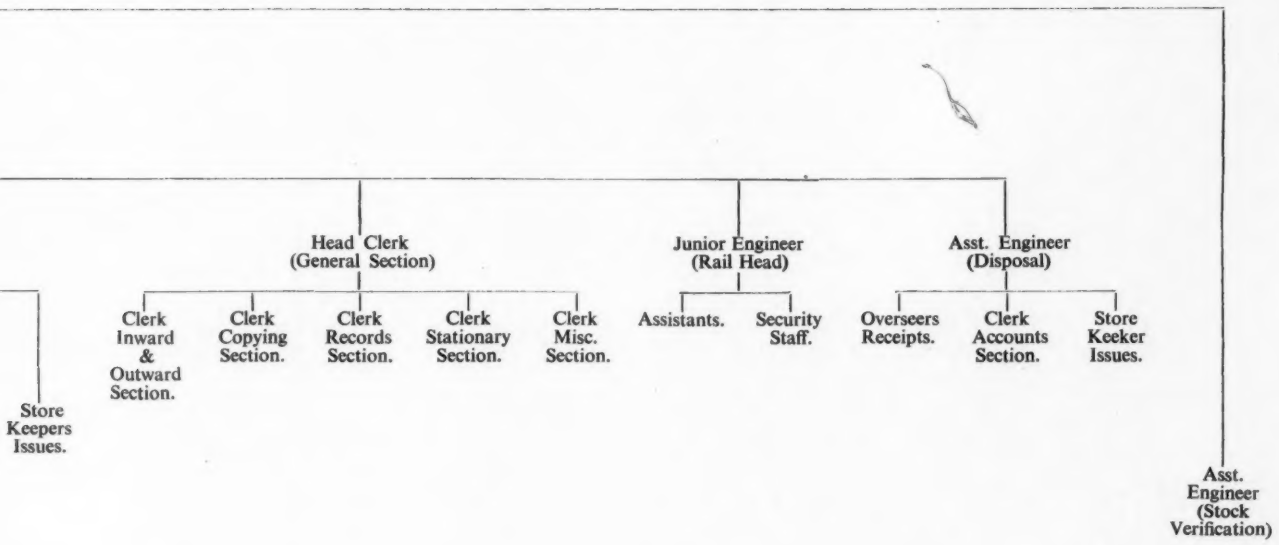
Due importance has been given to the verification of stores and there has been stock verification every year. An assistant engineer directly under the chief engineer is engaged for verification and each and every item in the Stores which at present totals to about 25,000 is verified. This annual verification has helped considerably in reducing the discrepancies which are negligible, in comparison with the large volume of stores handled. Apart from this, surprise random checks are also exercised by the stores officer and the assistant engineers.

(Continued on page 110)


Asst. Engineer (purchase)
Asst, Engineer (Receipts & Issues)
Divisional Accountan
Addl. Divisional Accou
Commercial Accounta
Supervisor (purchase)
Supervisor (purchase)
Purchase Assts.
Purchase Assts.
Junior Engineers & Overseers (Receipts)
Overseer Transport (of materials from JHW Road.)
Correspon-dence, claims.
Security staff.
Store Keepers (Issues)
Clerk Establish-ment Section.
Clerk Payments Section.
Clerk Adjust-ments Section.
Clerk Cash Sectio


CHIEF ENGINEER
SUPERINTENDING ENGINEER
STORES OFFICER
Divisional Accountant
Addl. Divisional Accountant
Commercial Accountant
Clerk Establish-ment Section.
Clerk Payments Section.
Clerk Adjust-ments Section.
Clerk Cash Section.
Clerk Ledger Section.
Clerk Misc. Section.
Asst. Engineer
(Branch Stores Dam Site)
Clerk Correspon-dence Section.
Security Staff.
Overseers (Receipts)
Store Keepers Issues.

Appendix "A"


Store Keepers Issues.
Head Clerk (General Section)
Clerk Inward & Outward Section.
Clerk Copying Section.
Clerk Records Section.
Clerk Stationary Section.
Clerk Misc. Section.
Junior Engineer (Rail Head)
Assistants.
Security Staff.
Asst. Engineer (Disposal)
Overseers Receipts.
Clerk Accounts Section.
Store Keeker Issues.
Asst. Engineer (Stock Verification)

Foundation Treatment at Gandhi Sagar Dam

By D. N. NAYATE

MANY old dams in India have been built without having any foundation treatment. The question that naturally arises is: are such old dams not standing for last so many years? And if yes, where is the necessity of any treatment to foundation? The answer is: in case of old dams the factor of safety was too much or in other words the sections of those dams were much more than those actually required on the treated foundations and thus uneconomical in cost. Further, merely providing over-sections did not ensure safety of dams and consequently there have been quite a good many failures too. But owing to recent developments in the science of soil mechanics and foundation treatment the foundations which were once considered not very sound for construction of masonry dams can now be successfully accepted for construction of earthen dams, thus utilising the river resources which otherwise would have remained unutilised. Foundation treatment particularly for the masonry dams, is comparatively a recent technique and has very much helped in not only ensuring more safety but also reducing the overall cost of construction.

ROCK FOUNDATIONS—TREATMENT

Foundation treatment in rock includes: (1) drilling and consolidation grouting, (2) deep curtain grouting, and (3) drilling drainage holes.

The main objects in treating the foundation of the dam are: (1) to increase the bearing capacity of the foundation rock by consolidating the whole foundation area into a solid mass by injecting cement grout which fills up the interstices and crevices in the natural rock and cements various blocks together; (2) to prevent passage of water directly below the dam and from its exerting uplift pressure and indirectly reducing the effective weight of the masonry structure and consequently making the dam more unsafe or requiring thicker sections involving more cost; [there are two methods in achieving this objective, the first is to fill up the cut-off trench by concrete and the second is to form the grout curtain consisting of holes drilled at frequent intervals and grouting under pressure. The grout curtain increases the path of percolation thereby reducing the quantity of water that percolates through the foundation]; (3) to release the seepage water if any, inspite of the above precautions, by drilling a series of drainage holes at certain intervals, connected to a system of drains and finally dispose of the seepage water by means of pumps or gravity.

DRILLING

Drilling is usually done by wagon drills and it is of percussion type. The diameter of holes varies from $1\frac{3}{8}''$ to $2''$ in case of consolidation and curtain grouting and $2\frac{1}{2}''$ to $3''$ in case of drainage holes. The holes are spaced as per certain pattern and drilled to a specified depth. The drilled holes are then completely washed and cleaned with jets of air and water under pressure alternatively until a clean wash is obtained. Suitable valves are used to permit continued or alternate injections of air and water into each hole and for quickly switching the flow from one hole to another, so as to produce turbulent action necessary to dislodge the materials. The water and air connections are changed at frequent intervals to cause water flow in every possible direction, through the seam.

WASHING OF HOLES

Washing of holes should, in both the cases (viz. consolidation and curtain grouting) not be completed too much in advance of grouting. Before grouting of a hole is taken up, the adjacent holes should be kept clean so that they are ready for grouting in case they are found connected with the hole being grouted. The pressures used for washing of holes vary from 30 to 50 lbs./sq. in. in case of consolidation grouting and 75 to 100 lbs./sq. in. in case of curtain grouting. In any case care should be taken to see that the pressures adopted do not lift the rock up.

As soon as the drilling of a pattern is completed and all holes blown clear of muck, wherever possible G.I. $1\frac{1}{2}''$ diameter pipe 18" long is solidly anchored in the drill hole with grout, mortar or lead wool and tightly caulked with lead wool or other suitable material. The pipe is plugged by a G.I. plug to prevent debris from entering the hole.

After cleaning of holes by air and water under pressure, the work of grouting is started. Cement grout usually consists of a mixture of neat cement with water. Thin grout travels farther than the thick grout. Hence it is customary to start with a thin mixture of 1 part of cement to 10 to 12 parts of water and gradually thicken the grout as the hole tightens. This procedure not only ensures reaching of grout into remoter seams but also offers a minimum disturbance of natural formation. A mixture of 1 part of cement to about 2 parts of water is frequently adopted for final grouting, where rock is loose a mixture of 1 of cement to 0.6 of water by weight has to be used.

Drilling for Consolidation Grouting.

GROUT EQUIPMENT

The apparatus used for mixing and injecting grout should be capable of effectively mixing and agitating the grout and forcing it into holes in an uninterrupted flow at any designed pressure even up to 500 lbs./sq. in. if required. A two compartment, open top, mechanically agitated mixer is used for mixing the grout. The mixer discharges by gravity into the suction of air driven duplex reciprocating grout pump. The pump and mixer should preferably be jointly mounted in skids or a three wheel truck capable of being readily moved to any part of work.

METHODS

Grouting is done by 'full depth' or by 'progressive stage method'. The former method is usually adopted in case of consolidation grouting and the latter in case of the deep curtain grouting. The depth of the stage may vary from 20′ to 50′. The maximum pressure adopted for grouting in case of consolidation grouting is 30 to 50 lbs/sq. in. and in case of curtain grouting 100 to 150 lbs/sq. in.

In shallow grouting operations are started on the side of pattern towards which seams dip, so that the trapped air may easily be forced out. Grouting is continued until the hole refuses to take any more grout at the specified pressure. Where grouting of the foundation is to be done after concrete or masonry has been placed no hole should be grouted until all concrete or masonry to a depth of not less than 10′ has attained sufficient strength. In such cases pipe nipples should be installed and necessary connections made for later grouting.

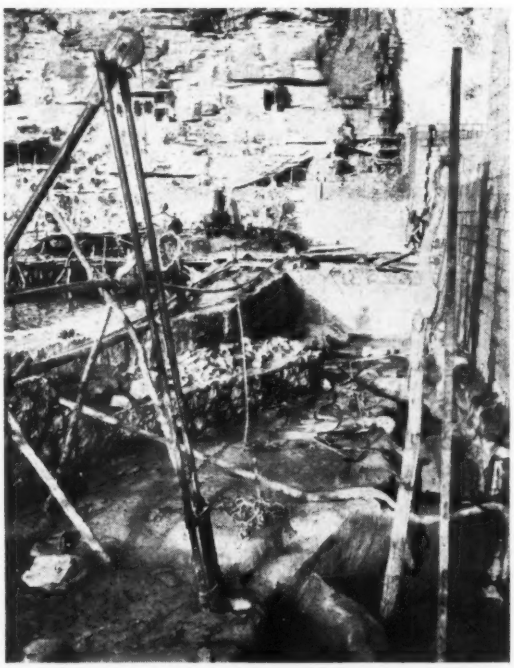
For the curtain grout split spacing method is adopted. According to this, the first set of holes drilled shall be widely spaced and grouted before intermediate holes are drilled. Then a set of intermediate holes is drilled and grouted before further intermediate holes are taken up and in this manner grouting is completed with such final spacing of holes as is necessary to obtain a continuous grout curtain across the foundation. Curtain grouting operations are started after constructing the masonry to a height of 80′ to 100′ above the foundations so that the foundation strata may not be uplifted due to the high pressures used for injection.

TEST HOLES FOR GROUT CURTAIN

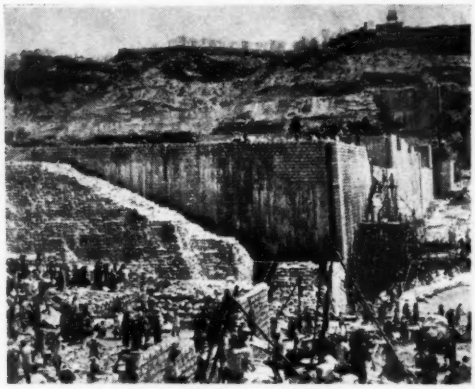
After grouting is done, to test the efficiency and penetration of grout in the grout curtain core drill holes should be drilled by means of a diamond drill; these holes are tested with air and water under pressure for complete tightness for a period about ½ hour in case of consolidation grouting and 2 hours in case of curtain grouting. After satisfactory test the holes are plugged with rich grout mix.

RECORDS

Drilling and grouting records should be kept neatly and systematically as the work progresses. The exact



Drilling for Consolidation Grouting.



Drilling for Deep Curtain Grouting.

location of all the holes with reference to axis of dam should be recorded and an accurate log of all operations kept. Records, drawings showing connection of holes with each other, if any, should be prepared. All information regarding the grout operation, amount of grout taken, effects observed in surrounding holes or rock, etc., should be kept.

Before taking up any work of foundation treatment it is absolutely necessary to study the geological nature of foundation and then decide the type of treatment, e.g. in case of shale strata drilling and grouting would not be so effective as in case of quartzite or granite.

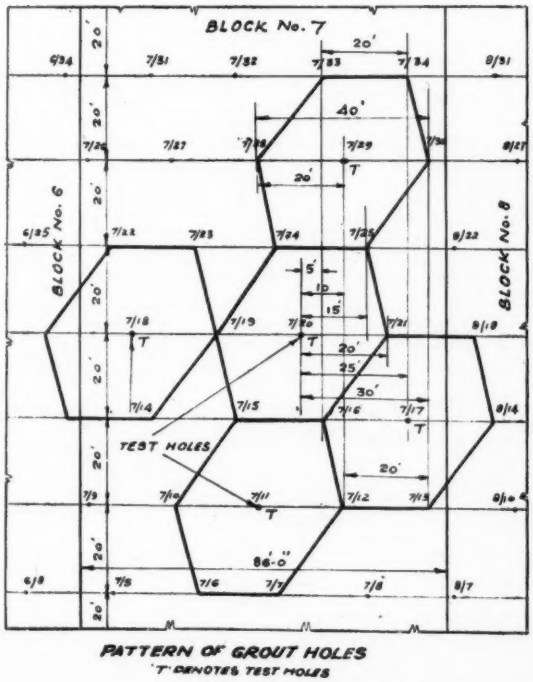


Fig. 'A'

DRILLING AND GROUTING AT GANDHI SAGAR DAM

Gandhi Sagar Dam is a masonry dam 1,250′ long at the river bed and 1,685′ at top (R.L. 1324), 175′ wide and 204′ high. The river bed consists of grey-whitish quartzite. The rock is laminated and fissured and therefore, definitely needed foundation treatment. The seismic tests and geophysical investigations conducted by the staff from Hydraulic Research Station, Poona, revealed that the thickness of this rock is about 130′ below the river bed and hence quite suitable for resting the dam of about 200′ in height.

DRILLING AND CONSOLIDATION GROUTING

After excavation of foundation to the required width and depth, $1\frac{7}{8}$″ diameter holes to a depth of

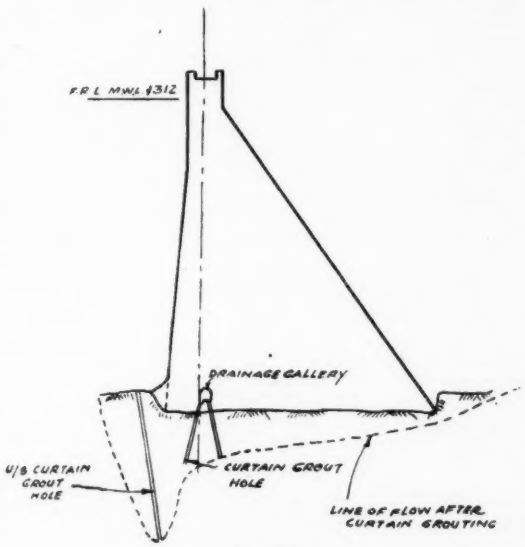


Fig. 'B'

20′ below the foundation bed were drilled by means of wagon drills. The hexagonal pattern of holes in plan consists of holes spaced 20′ apart in a line parallel to the axis of dam and each row spaced at 20′ the holes in the next row being staggered by 5′ with the adjacent ones. Fig. 1 indicates the pattern.

After drilling the holes to the required depth they are washed with water under a pressure of 30-40 lbs. per sq. inch. When the holes are cleaned of all the rock powder, dust, etc., cement grout starting from thinner consistency of say 28 lbs. of cement per 40 gallons of water or 7.0 per cent and gradually increasing to thicker consistency of as much as 225 lbs. of cement per 40 gallons of water or so, was injected under the maximum allowable grouting pressure, the idea being that the thinner seams be filled up with lean grout and wider seams with thicker grout. Grouting operation is continued till the hole

refused to take any more grout. After the cement grout has set for 24 hours or more, a few test holes inside the pattern were drilled and tested and grouted to see the effectiveness of grouting. In many cases connection between the holes (in some cases as many as even 10 to 12) was found and though grouting process in such cases was longer all these holes used to get filled up simultaneously. Similar consolidation grouting has also been done for machine foundations of power house; in this case the pattern being slightly different as shown in Fig. 1.

UPHEAVAL GAUGES

In order to detect any movement or upheaval of the foundation rock due to excessive grout pressure, unheaval or deformation gauges were installed prior to grouting operations. A 1″ diameter pipe was anchored by grouting to the bottom of the holes drilled 5′ deeper than the proposed grout holes. Above the anchorage the pipe was encased in a $1\frac{1}{4}$″ internal diameter G.I. pipe and the hole filled up with lean mortar. An iron yoke or bridge was anchored to the surrounding rock. Measuring tips were set at the top of the pipe and on the underside of the yoke. The gap between the tips measured with a thickness gauge during grouting operations. Actually no upheaval was noticed (Fig. No. 1).

FOOTAGE AND CONSUMPTION OF CEMENT

In case of Gandhi Sagar Dam the total footage drilled was 38,671 and at a total cost of about 9.50 lakhs (including the cost of cement, water, lighting, etc.) The average consumption of cement was 1.50 c.ft. per rft. of hole, the maximum quanttiy of cement in one particular hole was 650 bags. In general it can be said that the behaviour of foundation was fairly good.

V—SERIES

In addition to above a few holes called the 'V' series along the rock ledge and about 70′ to 80′ in depth, at right angles to axis of dam, to prevent circumvention of water there, were also drilled and grouted.

DEEP CURTAIN GROUTING

As mentioned earlier the deep curtain grouting is done on the upstream side of the dam and it prevents passage of water directly below the dam or in other words the upstream curtain acts like a cut-off wall. Thus it prevents uplift pressure being exerted by water adversely affecting the stability of dam.

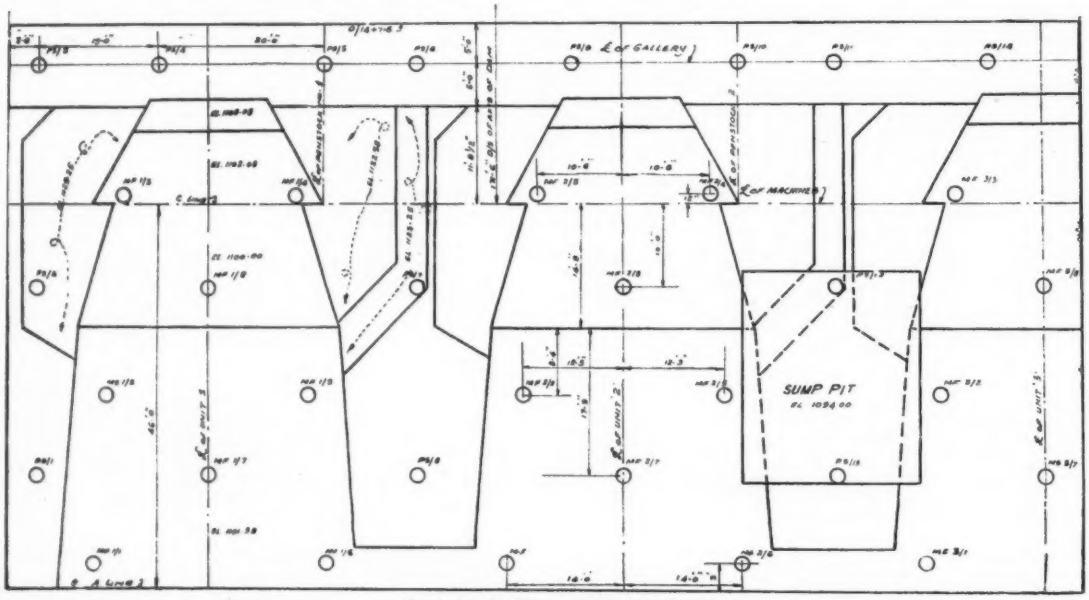
TWO LINES OF GROUT CURTAIN

Two lines of grout curtains were proposed, one at the heel of the dam and the other through the drainage gallery.

As per the general practice the depth of grout curtain is determined by the following formulæ:—

(i) $d = \frac{1}{3} h + c$.

(ii) $d = 0.42\ h$.



EXCAVATION PLAN OF POWER STATION

HOLES OF 'PS' SERIES TO BE GROUTED AFTER THE CONCRETE HAS COME TO THE LEDGE LEVEL

Fig. 1.

where d is the depth of deep curtain grout hole in feet, h is the height of the structure in feet above the hole, c is a constant usually varying from 25′ to 75′. In case of Gandhi Sagar Dam primary holes of 75′ depth, secondary holes of 100′ depth and tertiary holes of 150′ depth inclined at 5° to 10° to vertical and towards downstream were drilled in the beginning; but later on, as per advice of Central Water and Power Commission, most of the holes of 100′ depth were drilled, as they were considered to be adequate for this type of dam and rock. The spacing of the holes was kept at 64′ and then reduced to 32′, 16′ and 8′. In case of some portion, the holes had to be drilled at intervals of as close as 4′.

These holes were then cleaned of all rock powder, muck, etc. by means of air and water under a pressure of 100 lbs/sq. inch. Then as in case of consolidation grouting the grout starting with leaner mix and gradually increasing to a thicker one, was injected under a pressure of 100 lbs/sq. inch. In front of diversion blocks (No. 4 & 5) as the height of masonry over the foundations was less than 80′ only, drilling was done simultaneously with the nearby blocks but the grouting operations were taken up only after the height of the dam had come up to 80′ to 100′ above the foundations within a distance of up to 200′.

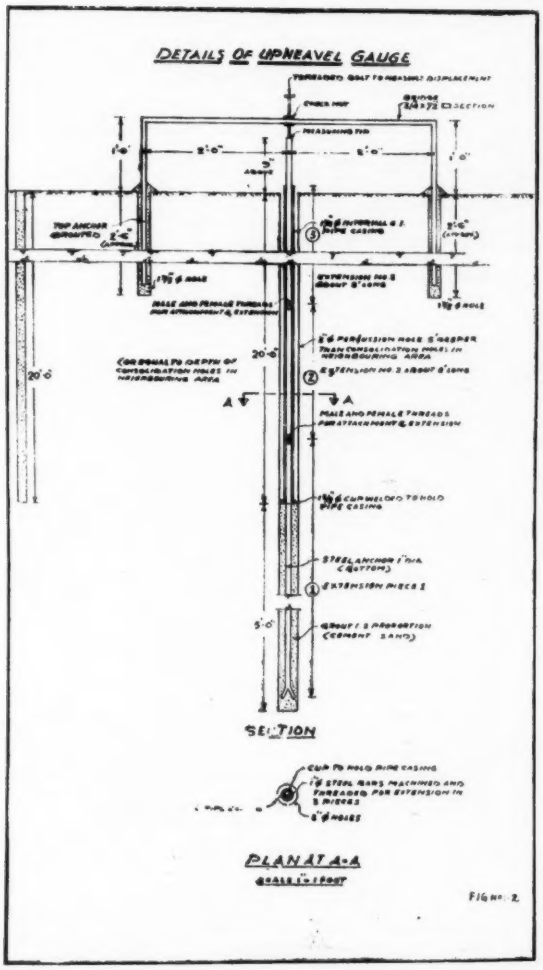


Fig. 2.

FOOTAGE AND CONSUMPTION OF CEMENT

The total number of holes drilled added up to a total footage of 24,546 rft. at a total overall cost of Rs. 7.12 lakhs. The average consumption of cement was 0.52 cft. per rft., the maximum in any case being 18.0 cft. per rft.

The second line of curtain grouting through the drainage gallery is proposed. This was considered necessary as the uplift pressure gauges installed in the foundation of dam in two blocks, viz. 7 and 15 indicate some uplift pressure but well within the assumed uplifts.

DRAINAGE HOLES

Drainage holes, as already stated earlier, help in releasing pressure due to flow of water if any inspite of the consolidation and deep curtain grouting directly below the foundation of dam. The same pressure gauges mentioned above indicated that when a drainage hole is drilled in the drainage gallery there is a drop in pressure from 3 to 5 lbs. per sq. inch, indicating the necessity of such type of holes for release of pressure. In case of Gandhi Sagar Dam this work also is yet to be done. It is proposed to drill such drainage holes about 3″ in diameter through the drainage gallery at an interval of 20′ staggered with curtain holes through drainage gallery mentioned above, and a depth of 40′ is proposed to be adopted in this case. The water released from these holes will be collected in a drain and finally into a sump well and pumped out.

SPILLWAY BUCKET DRAINAGE SYSTEM

Drilling of 3″ diameter, 10′ deep drainage holes in the bucket portion of the spillway at a spacing of 12′ in a direction perpendicular to the axis of the dam and at a 40′ C/C in a direction parallel to the axis has already been done. Total footage drilled was 2,296 rft. and expenditure incurred Rs. 0.52 lakhs. These holes are connected to a series of drains (shown in the drawing) and the released water is finally disposed of through vertical pipes.

DRAINAGE SYSTEM FOR DRAFT TUBE

1 $\frac{7}{8}$″ diameter drainage holes 10′ to 12′ deep were also drilled in the draft tube area, eight per each unit and the spacing of the holes varies from 5′ to 10′.

(Continued from page 54)

HIGH VOLTAGE GRID SUB-STATIONS IN CHAMBAL PROJECT (M.P.)

tection is provided in addition to distance protection. The 66 kV lines from Ujjain are all provided with distance protection. The 66 kV line from Neemuch to Mandsaur is provided with over-current and earth-fault protection only at Neemuch end. All 33 kV and 11 kV outgoing feeders are provided with over-current and earth-fault protection.

GROUNDING

For grounding the switchyard equipment and structures, a grounding mat is provided at each sub-station to secure as low ground resistance preferably 0.5 ohm or less.

INDOOR EQUIPMENT

The control panels are of sheet steel cubicles on which the control switches, relays, meters, indicating lamps, semaphores, and annunicators are mounted.

The control and emergency power available at 110 V.D.C. from lead acid batteries and charging rectifiers at all sub-stations except at Ratlam and Mandsaur where 30 V alkaline cells are provided.

The 400 V.A.C. supply for lighting and colony supply is obtained from station service transformers in the switchyard and the 400 V switchgear in the control room building.

The 11 kV panels are all indoor type metal-clad units comprising switchgear, relay, meters etc. and the outgoing feeders are taken out from the 11 kV bus by cables.

(Continued from page 104)

STORES ORGANISATION IN CHAMBAL HYDEL SCHEME

DISPOSAL WING

With the nearing of the completion of the project a Disposal Wing has been started in the Stores. Lists of items which are likely to become surplus have been prepared and sent to the field officers concerned for their opinion regarding their being declared surplus. Stores so declared, would be disposed off by transfer to other projects or departments or by sale through the agencies appointed for the purpose. But the amount of stores that would be rendered surplus is not expected to be very much.

It may be worth considering whether the system adopted in this project of appointing a non-technical officer to work as stores and purchase officer is desirable. Looking to the performance during the past few years, it is felt that such an arrangement should work satisfactorily in any project provided suitable person with suitable experience and sufficient background is available. The history of the stores in this project has clearly demonstrated that technical personnel are averse to being posted in stores, there being a feeling among them that their talents would be wasted in such a place. Therefore a very careful selection of suitable person for this very arduous job is one of the most important requisites for the successful functioning of the stores. While having due regard for the accounts side of the work, he would also feel a sense of responsibility for the task on hand.

In conclusion, it may be mentioned that a well-established Stores Organisation is of utmost importance for the successful working of any project and it should be given due importance and sufficient priority. No work can be started without purchasing stores, it is therefore necessary to establish an organised stores with adequate and sufficiently experienced staff from the very beginning.

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Rehabilitation in Chambal Project (M.P.)

By TILLURAM

ON completion of the Gandhi Sagar Dam, a man-made lake of 265.90 sq. miles will be formed submerging partially or fully, 228 villages 73,000 acres of agriculture land under holdings and 94,000 acres of Government land. About 51,500 persons would be displaced. The lake also submerges 2 high level causeways on Chambal river and 23 miles of metalled road, dislocating thereby direct communications between important towns.

Restoration of communication and rehabilitation and resettlement of displaced persons are the responsibilities of the project authorities. Rehabilitation and resettlement of displacees comprises : payment of reasonable compensation for their immovable property going under submersion; providing culturable land wherever available to continue their age-old profession of farming; providing facilities for transportation of immovable property; providing technical help in laying out villages; and providing, in the new villages, common amenities like public buildings, fair weather roads, tanks, wells etc.

In the initial stages one Land Acquisition Officer and one Assistant Engineer were appointed for this rehabilitation and resettlement work. Later on this establishment was incresed to one Executive Engineer, two Land Acquisition Officers, and one Rehabilitation Officer with necessary staff to expedite the work and complete the rehabilitation and resettlement within the time schedule as the water started collecting in the lake on the closure of construction sluices of the dam.

The function of Land Acquisition Officer, was to pay compensation for immovable property. One Assistant Engineer, was attached to each of the Land Acquisition Officers to help them in valuation of buildings and wells. The Rehabilitation Officer was to make available land, village sites and settle the displacees in new environments. The Excecutive Engineer took in hand the construction of tanks, wells, public buildings, fair weather roads etc., in 1959.

Claims were settled very amicably. The compensation was paid after classifying land into three categories, viz., (1) irrigated land; (2) cultivated land and (3) un-cultivated land.

Compensation of buildings, wells, trees, open platforms, cattle shed etc., was paid on the prices pre-

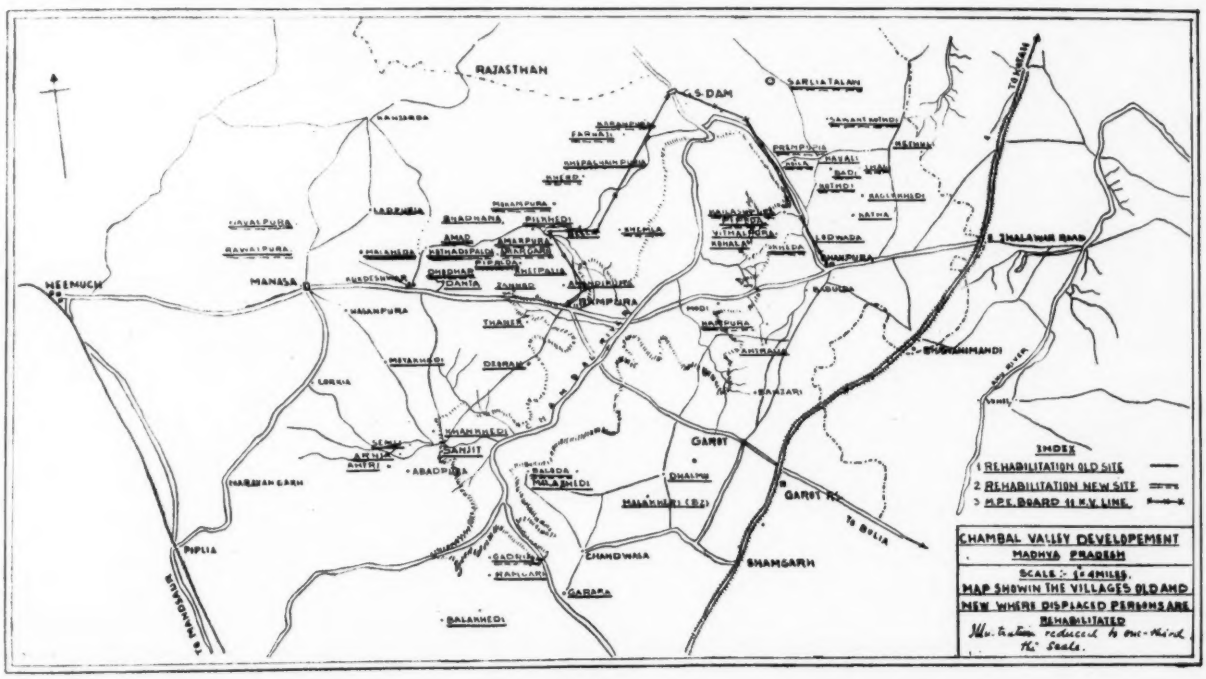


Fig. 1

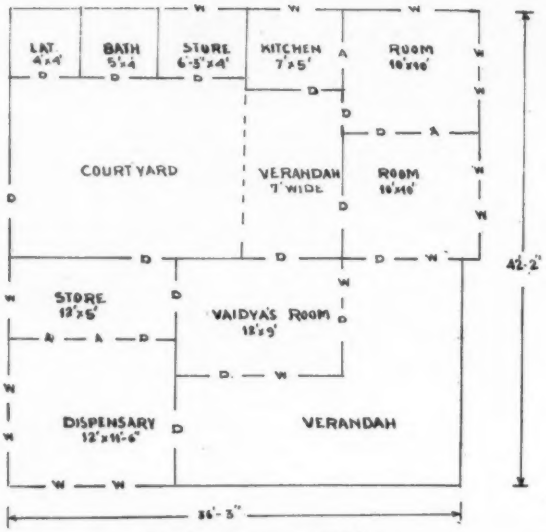


Fig. 2—Dispensary building.

valent at the time of notification under section 4 of the Land Acquisition Act. The land was valued as under:—

	Value in rupees per acre		
	Irrigated land	Cultivated land	Uncultivated land
Uttam land	375	125	90
Madhyam land	350	105	70
Kanisht land	325	95	60

Valuation

(a) *Residential buildings:* The houses were divided into three classes for compensation (1) pucca houses, (2) semi pucca houses and (3) kachha houses. The basis for payment of compensation for these buildings is the material used for construction and plinth area. The rates paid for compensation as follows:

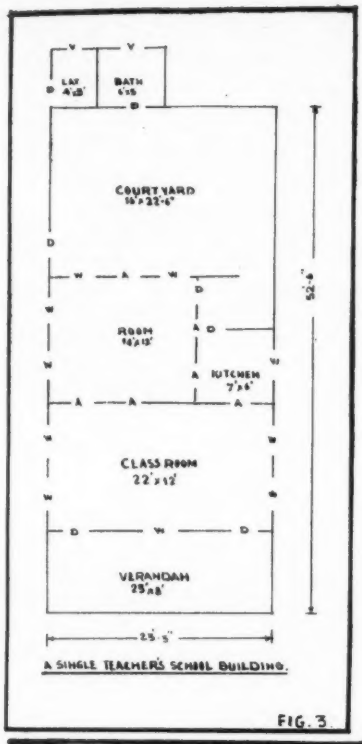
Class of house	*Rate per sft. of plinth area*
(1) Pucca	Rs. 7.00 to Rs. 6.00
(2) Semi pucca	Rs. 4.56 to Rs. 3.37
(3) Kachha	Rs. 2.00 to Rs. 1.50

Cattle sheds were valued at Rs. 0.50 per sft. of plinth area. House sites were paid at Rs. 0.78 per 100 sft.

(b) Wells: The average compensation paid for pucca, semi pucca and kachha wells was Rs. 5500, Rs. 4000 and Rs. 1600 respectively and this took into consideration the diameter and the depth of the well.

(c) Trees: Compensation for fruit bearing trees, like Khirni and Mango was paid at Rs. 50.00 to Rs. 100.00 per tree.

The nature of acquisition being compulsory an additional 15 percent was paid to the property holders in accordance with Land Acquisition Act, 1894.



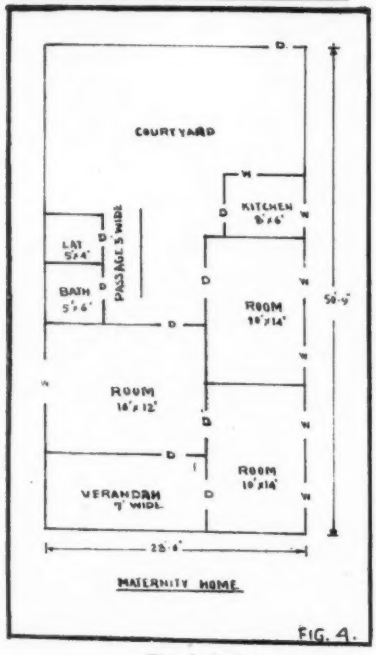


Fig. 3 & 4.

Incidential charges due to the change of residence were being paid at 2 percent of the cost of houses they held, with a minimum of Rs. 10 and maximum of Rs. 60.

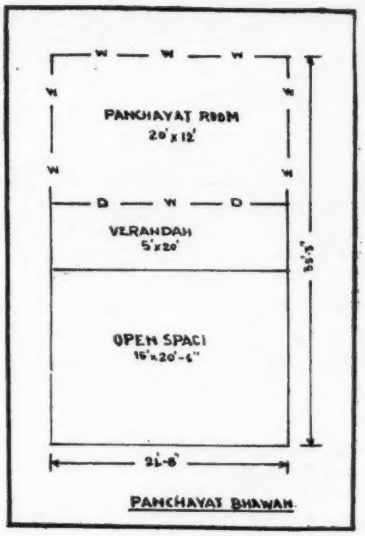


Fig. 5

All cultivable land within a radius of 30 miles from the periphery of Gandhi Sagar is reserved for rehabilitating the displaced persons. In addition, reclamation of forest land and fallow land in revenue blocks was done to provide land to the displacees. Allotment of land is the duty of Rehabilitation Officer. The basis for allotment is: land for land, or cash compensation, whichever the owner desired. For those persons such as artesans, labourers who had not received any compensation or received compensation less than Rs. 500, provision is made to pay a minimum of Rs. 500 as rehabilitation grant. In the new village sites, plots for houses are allotted. The houses are built according to the choice of displacees.

PROBLEMS

The local labour is predominently agricultural; and they, therefore, come to work barely four to five months in the year, November to March. The rehabilitation works were in the interior and outside labour were not willing to work due to language difficulties. Almost all such works had to be carried out departmentally because of poor response to tendors. Executive staff being used to urban life found it very difficult to adopt themselves for the requirements of the rehabilitation work. Hence considerable difficulties had to be overcome to keep up to the targets. Departmental works require a liberal supply of transport vehicles for shifting materials and labour.

Construction of Public Buildings

Local materials were used for public building construction in Rehabilitation blocks. For example murum blocks with 5 percent of cement were used for the interior walls and the buildings are standing successfully the load. Plans adopted for various public buildings are as shown in fig. 2, 3, 4 and 5.

A rare feature: Another important problem to be faced was protecting Rampura town from submergence. (Fig. 6). It is not only a flourishing town but is of great religious importance for Boara community. At full tank level the reservoir will submerge low lying areas of Rampura. Many alternatives were considered to solve this problem by an expert committee set up by the Chambal Control Board and they finally decided to protect the town by the construction of an earthen ring bund. This bund is 6400′ long having a top width of 20′. The maximum height of the bund is 30′ and average height, 20′. A ten acre sump will be created on the town side of the bund to collect the storm water from the town from where the water will be pumped into the reservoir. To minimise the pump capacity rain water, as much as possible, is diverted at higher levels directly into the reservoir by a catch-water diversion drain constructed at the foot of the hill on which Rampura town is situated. The catch-water drains will intercept a catchment area of more than a square mile. A provision of Rs. 22 lakhs is made in the project estimate for Rampura ring bund and appurtenant works.

The pumping sets will be used only for a few months in a year. To put the pumps to optimum use and to derive better benefit from this installation, surveys are under progress to investigate the possibility of lift irrigation of adjoining lands of Rampura town. (Fig. 6 on next page).

(Continued from page 125)

ORGANISATION SET-UP OF CHAMBAL PROJECT

and the Collector of the District concerned. 3 Land Acquisition Officers and a Rehabilitation Officer have been provided to the Collector for this work both for head works and canal works.

In the year 1955, the Central Government in consultation with the two State Governments constituted the Chambal Control Board which is in overall control of the project including its technical and financial aspects. The Chambal Control Board is not a statutory body and works in the advisory capacity. A convention has however been established by which decisions of the Chambal Control Board are accepted by the State Governments.

Since the works are being completed, a separate office under an Executive Engineer has been established who will take over records, T. & P. from offices which are being closed and will transfer the same to the Departments of the State responsible for maintenance of the project after its completion. A separate Assistant Employment Officer has also been provided for arranging absorption of surplus staff, from the project in other departments through Employment Exchanges. Most of the staff is likely to be taken over by the M.P. Electricity Board and the Irrigation Department of the State who will take over the project for maintenance.

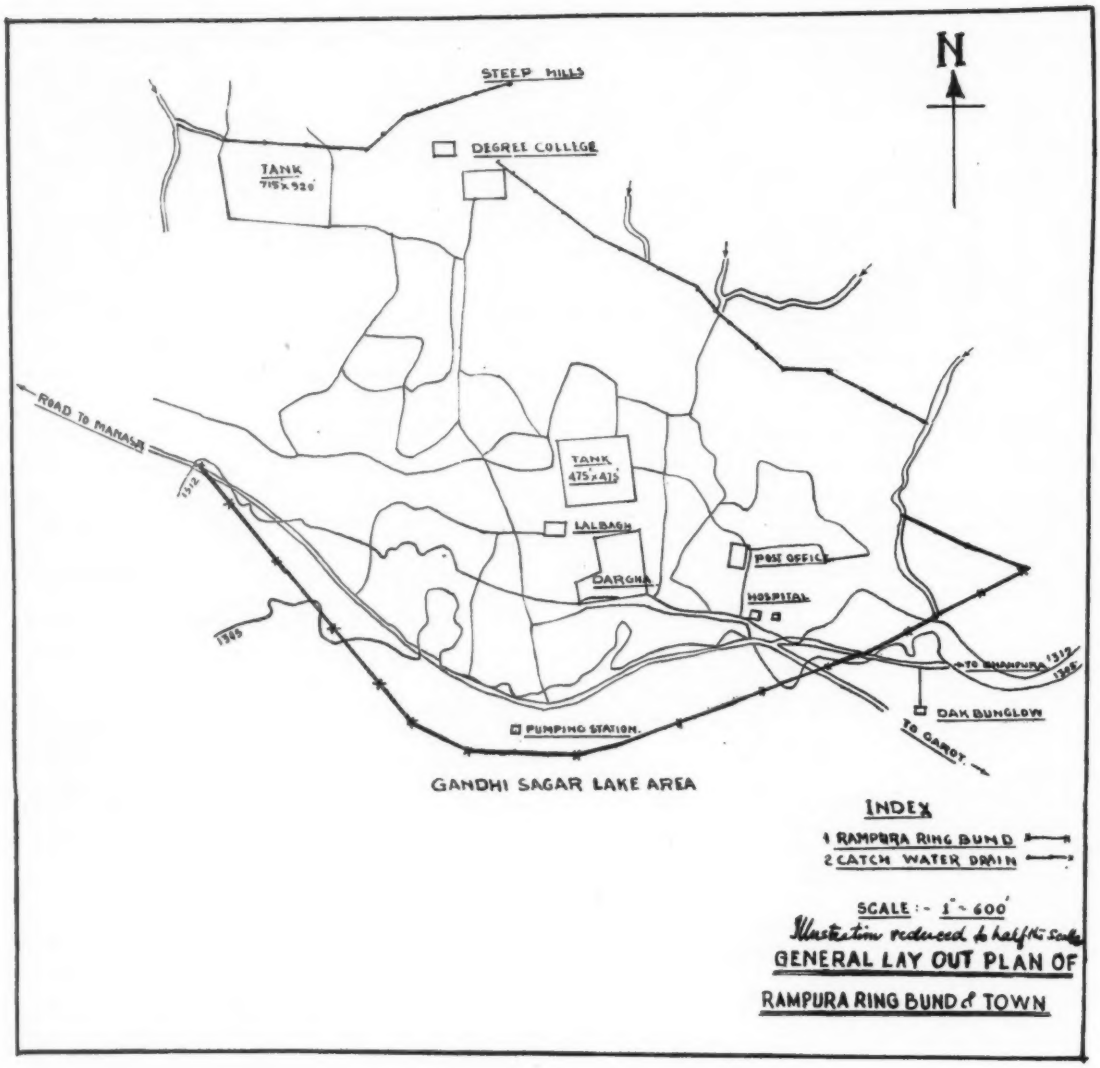

N
STEEP HILLS
DEGREE COLLEGE
TANK
715'x520'
ROAD TO MANASA
TANK
475'x415'
LALBAGH
DARGHA
POST OFFICE
HOSPITAL
PUMPING STATION.
DAK BUNGLOW
TO GANDHI SAGAR LAKE AREA
INDEX
1 RAMPURA RING BUND
2 CATCH WATER DRAIN
SCALE :- 1" ~ 600'
Illustration reduced to half the Scale
GENERAL LAY OUT PLAN OF
RAMPURA RING BUND & TOWN

Fig. 6

Industrial Relations at Gandhi Sagar Dam and Power Station

By L. J. KALE

FEW problems in a planned economy of any democratic country are of greater interest and importance than that of Industrial Relations. Industrial peace which is the fruit of smooth and straight industrial relations is of very great importance and cannot at any cost be staked if the speed of economic progress and development of the country has to be accelerated according to the phased programmes.

The problems of industrial relations in a major project, which is usually situated in an out-of-the-way place, and which is not a permanent undertaking, cannot be compared to a stable and organised industry. All basic requirements of human life, namely, housing and sanitation, water-supply and electricity, health and education, supply of provision and other necessities of life, first need systematic tackling in order to attract labour to join the project and work. Added to these are the regular industrial matters of hours of work, wages, working conditions, safety and welfare and such other problems which deserve immediate attention and solution to ensure a stable and contented labour force.

RECRUITMENT & COMPOSITION OF LABOUR

The recruitment of labour, no doubt, presented its own difficulties in the initial stages as is usual with every project, but soon the conditions of living and work stabilised and more and more labour, both skilled and unskilled joined the works, and the construction of the dam and power house progressed satisfactorily and peacefully. In the words of our chief engineer "men and machines equally contributed to the construction of the project, and no total mechanisation of the project was effected keeping the employment problem of the nation quite in forefront".

The total number of labour employed, departmentally as well as by contractors, is represented in the graph given below. It will be observed from the graph that the peak labour force was employed in the first two quarters every year, and it was the highest in 1959 and 1960 and progress of work was at its peak. During monsoon months labour force was always at a low ebb, and it gradually increased in winter months reaching its peak in February and March every year.

Skilled and unskilled labour joined the works from almost every part of the country and project colonies presented a form of miniature India. The South Indian labour mainly specialised in quarrying, stone-cutting, stone-dressing, hand-drilling, blasting operations, and masonry work; while the Khandeshi workmen did number of jobs including loading, unloading and carting work. Local labour came from the adjoining parts of Malwa and Rajasthan and included skilled and semi-skilled workers mainly *bandhanies*, carpenters, masons, mistries, etc. Many of them were useful and responsible for getting large number of unskilled labour. The Rajasthani labour formed the bulk of unskilled workers and stone-lifters, while U.P. men and Gurkhas were mostly seen on sentry duties as guards and chowkidars. The Punjabis were mostly employed as Khallasis and skilled workmen, Moplas for erection of gates, etc. Besides, specially skilled workers were also drawn from the completed projects in other parts of the country.

In the ranks of unskilled and semi-skilled labour, barring very old and young persons, most families were multi-worker families and this was especially so amongst the South Indian, the Rajasthani and the Khandeshi labour.

WAGES & SALARIES

The total number of departmental workers in skilled and semi-skilled categories in different units of the civil and mechanical divisions of the dam and electrical circles is near about 2,000 and they are all mostly borne on the work-charged establishment as monthly paid employees. Their service conditions are governed by work-charged rules specially framed by the Government for the Chambal organisation, and they provide a benefit of 15 days' casual leave in a year besides provision for earned leave.

The Chambal Control Board has sanctioned maximum daily wage rate and consolidated monthly pay for daily wage-earners and work-charged employees respectively on category-wise basis, and individual skill and experience in a particular trade provides a good guide for fixing pay of craftsmen. In all there are as many as 133 categories of different trades and occupations including mechanical, civil and other jobs. The rate of daily wages normally range between Rs. 2/- and Rs. 6/- per day, and in cases of a few occupations requiring specialised skill and demanding greater responsibility, wage-rates have been fixed still higher between Rs. 8/- and Rs. 13/- per

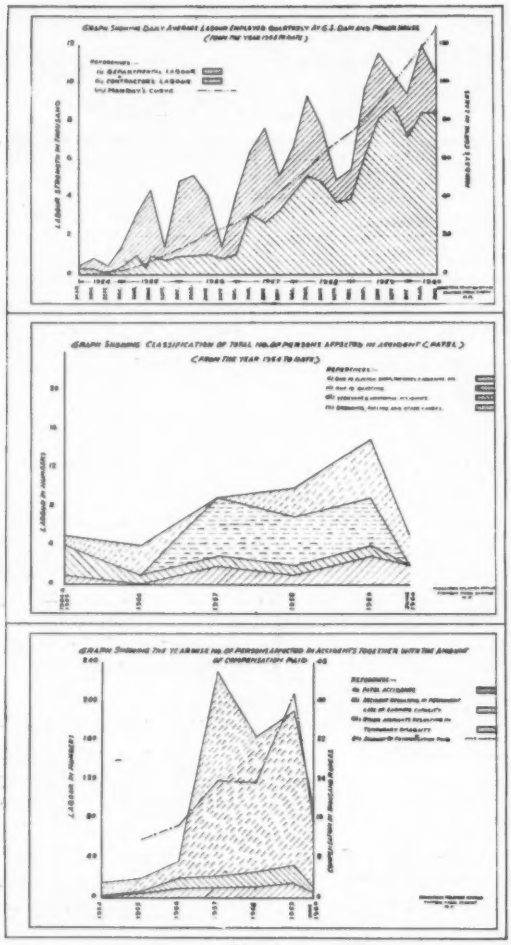


Fig. 1.

day. Fixation of salaries of such workmen favourably compares, mostly on higher side, with that of the minimum wage laid down for semi-skilled and skilled categories under the Minimum Wages Act. For deciding cases of promotion, regular trade tests are being held, and further, the following scales of annual increments have been sanctioned by the Government for work-charged employees in their own line.

Scale of salary of work-charged employee:	*Rate of annual increment sanctioned*
Getting upto Rs. 50/- P.M.	Rs. 3/-
Getting above Rs. 50/- P.M. and upto Rs. 100/- P.M.	Rs. 5/-
Getting above Rs. 100/- P.M. and upto Rs. 200/- P.M.	Rs. 10/-
Getting above Rs. 200/- P.M.	Rs. 15/-

The minimum rates of wages in respect of employments covered under the Minimum Wages Act and applicable to the project areas are as under:—

Clerical	Rs. 50/- per month.
Skilled	Rs. 3/- per day.
Semi-skilled	Rs. 2/- per day.

Unskilled.

Male	Rs. 1.37 per day.
Female	Rs. 1.12 per day.
Child	Rs. 1.00 per day

In the project an unskilled male labour receives a minimum wage of Rs. 1.50 to 1.75 per day, an unskilled female worker receives between Rs. 1.12 to 1.25 per day, and a child Re. 1/- per day. These rates of minimum wages are also being paid by the contractors to the labour employed by them.

Usually there would be an exodus of the unskilled labour before the Holi festival. To prevent such exodus, the project authorities were giving an increase of 0.25 to 0.13 n.P. per day upto end of June for all the unskilled labours working on daily wages. This succeeded in holding back the labour on to the work.

It is worth mentioning that 50 to 60 per cent of the total work-charged employees of the project who initially worked as unskilled workmen, after having received in-plant training in different trades in the units of the mechanical and civil divisions, are now categorised and paid salary of semi-skilled and skilled workmen.

EMPLOYER-EMPLOYEE RELATIONS

The history of industrial relations in the project is quite happy, and harmonious relations continued between employer and employees during last 10 years. So far there was only one major strike of 7 days' duration; and two lightning strikes, one affecting partial work of the project for 3 days and the other related to single shift closure by truck-drivers employed by the contractors. This may be the first project in the country where practically industrial peace continued undisturbed and work progressed unhampered without any major labour crisis.

This unique position is enjoyed by the project under the enlightened labour policy of the Labour Minister Shri V. V. Dravid, who is also the Minister incharge of the project. Under his able guidance from the inception the employees and workmen of the project enjoyed substantial facilities in the form of free housing, water, electricity and medical aid. All categories of workmen received higher wages than provided by the State under the Minimum Wages Act; and classes I, II, III, and IV employees received compensatory allowance at the rate of 30 per cent of their salary upto Rs. 200/- and at 20 per cent above Rs. 200/-, in addition to pay scales at the State level and usual D.A.

The continued industrial peace could only be ensured by keeping constant vigilance over the timely

payment of wages to all departmental as well as contractors' labour, and not less than 250 inspections were carried out every year by the office of the Industrial Relations Officer under the Minimum Wages Act to enforce the provisions of the Act and protect the wages of the wage-earners.

WORKMEN'S COMPENSATION

The prime importance was always given to cases of employment injuries, and the workmen, in cases of major and minor accidents received immediate free and full medical help in the project hospital besides free diet during the hospitalisation period. The project has a well-equipped 64-bed hospital with X-ray unit, pathological laboratory, operation theatre, and an ambulance van. Over and above, the compensation payable under the Workmen's Compensation Act was expedited without delay and paid to an accidentee to afford timely relief to him and to his dependents. A graphical depiction of number of accidents and amount of compensation paid is given below. In cases of fatal accidents, the payment of compensation to the dependents of the deceased workmen through the Court of the Commissioner for Workmen's Compensation was quite expeditious. The Collector, Mandsaur District, who is also the Commissioner for Workmen's Compensation for his own District has been personally looking into workmen's compensation cases and greater attention has always been paid to render timely relief to the accidentees and their families. In most cases of fatal accidents payment of compensation was made within 4 to 6 weeks time from the date of accident. Litigation under the Workmen's Compensation Act was the least and in all, hardly 5 cases were canvassed in the Court by workmen against employer. The Medical Officer's contribution in rendering missionary service to the accidentees in particular and to all employees in general was greatly responsible in establishing better human relations.

INDUSTRIAL DISPUTES

In the field of settlement of industrial disputes, which were mostly individual and collective applications from workers for wage increase, promotion, over-time payment, termination of services, etc., etc., immediate probe was made and timely relief was given to employees concerned. The co-operation and understanding between the Labour Department and the project authorities was noteworthy and the Industrial Relations Officer being under the administrative control of the Labour Department, always enjoyed a great advantage in the able guidance of the Commissioner of Labour in solving major and complicated disputes, besides the day-to-day administrative supervision and guidance of the Assistant Labour Commissioner, Indore Division, Indore.

With the conclusion of the project work quite in sight, the problem of prospective unemployment deserved due attention and timely solution. In this respect the Government have already taken positive steps to absorb and integrate the services of technical, and ministerial personnel of the project to the extent it can, with the Department of Public Works, Irrigation and B. & R., and the Madhya Pradesh Electricity Board which are the organisations finally to take over the maintenance of the dam and power house after their completion. Further all State Departments have been requested by the General Administration Department of the Madhya Pradesh Government to give priority in employing the surplus staff of the project in future appointments. Action is being taken to circulate the list of surplus staff to all Departments and the Employment Exchanges of the State.

View of a creche.

LABOUR ORGANISATION

There have so far been two organisations of the employees of the project and both are registered under the Trade Unions Act. The Gandhi Sagar Mazdoor and Karmachari Sangh came into being as early as in 1954, and is affiliated to the national organisation, Indian National Trade Union Congress. The union membership mostly consists of the work-charged employees, and it has been instrumental in getting benefits of work-charged rules, annual increments, promotions by trade tests, etc., etc., to the work-charged people. The other union, the Chambal Employees Association organised by Class III and IV employees of the project was formed early in 1959, and carries a membership of about 1,000 employees. The anxiety for the future of class III and IV employees (who are near about 2,200 in the whole organisation) after completion of the project work was the main reason responsible for the coming up of the Association at such a late stage of the scheme. Recently an agreement has been reached between the two unions to amalgamate them and keep it affiliated to the INTUC. The proposals of amalgamation have been forwarded to the Registrar of Trade Unions for registration.

LABOUR WELFARE

The welfare of the project employees received careful attention of the project authorities, and almost every essential amenity of life has been provided for. (*a*) *Housing, Water and Electricity*:—Housing has been provided free to all categories of employees including the contractors' labour. The project have constructed as many as 3,300 quarters, which include all types of constructions. Every quarter has been provided with free electricity; and adequate filtered water on the community basis has freely been made available to every labour colony. Besides, contractors constructed for their labour more than 1,000 huts, and the project has provided such labour camps with free community water, street electric lights, and surface drains. Filtered water-supply to the whole project colonies has proved a successful preventive measure against cholera, typhoid and such other water-born diseases.

(*b*) *Health and Sanitation*:—As already mentioned the project has a well-equipped 64-bed hospital at the construction camp and a dispensary at the Gandhi Sagar Colony. General medical help is provided free to all, while the project employees receive free and full medical treatment in cases of accident. Prevention of general diseases like malaria, small-pox, cholera, typhoid, etc., is given due attention and measures of malaria control, inoculation, vaccination, etc., are followed to check the breaking out of any epidemic.

(*c*) *Education and recreation*:—The project has provided free school buildings to the Education Department of the State, and the Department is running a Middle School and a Primary Girls' School at Gandhi Sagar Colony, and a separate Primary Boys' School and Primary Girls' School at the Construction Camp. Besides three Tamil Schools were run at the labour camps of the contractors for the children of South Indian labour under the auspices of the Labour Welfare Organisation of the project.

Both colonies have separate open air cinema, theatre, while the project employees have organised their own cine club and enrollment of membership is on family basis. The project also owns a 16 MM projector and every fortnight documentaries of different varieties are screened for the education and entertainment of the workers and their families.

(*d*) *Co-operative store and fair price shop*:—The employees of the project have organised the Gandhi Sagar Co-operative Society which is registered under the State Co-operative Societies Act. The Society has opened two provision stores, one at each colony and the buildings have been provided free of rent by the project.

For the benefit of working class, the Government of Madhya Pradesh has specially opened two fair price shops of wheat, one for each colony where the grain is sold at the controlled price. Prior to the transfer of territory of the Construction Camp from Rajasthan to Madhya Pradesh, great difficulty was experienced in the movement of foodgrains, the project being located on the borders of two States. Then the fair price shops were the main source of grain supply to labourers.

(*e*) *Creche*:—Creche is an essential amenity for working mothers where they can leave their children properly looked after. Under the supervision of the Project Medical Officer two creches have permanently been maintained at the works site. Each creche has a capacity of accommodating 50 children of ages between 3 months to 7 years. Children are classified as infants, toddlers and children. They are given every day free milk, diet and general education. They are also taught to live neat and clean by providing them bath, hair oil, comb, and clothes at the creche. During peak period of the works two more creches are put up to cope with the increasing number of children.

(*f*) *First aid centres*:—At important points of the construction site 4 to 5 first aid centres have been put up for rendering immediate first aid to workers in case of accidents or ordinary ailments. A trained compounder has been put in charge of each centre with requisite medicines and first aid appliances.

(*g*) *Labour welfare centres*:—Two labour welfare centres have been organised since 1956, one at each colony. Every centre has been provided with a radio set, reading room and indoor games. The building has been provided free of rent by the project. Seven volley ball teams in different localities of the township are functioning and every year on occasions of Independence Day and Republic Day competition of sports and games are arranged to encourage sportsmanship and fellow-feeling amongst working class and suitable prizes are awarded to winners.

A Community Hall has been constructed at C.S. VII labour camp which is the biggest labour locality of departmental labour. It has been provided with open premises where swings and a slider have been installed for the children of labour. The Hall has a

(Continued on page 124)

View of a Departmental Colony at C. S. VII.

Land Acquisition for Chambal Canals in Madhya Pradesh

By S. B. RANE

COMPULSORY acquisition of land for purpose of projects included in the Rural Development Scheme, has assumed great importance under the Indian economy as streamlined by the Five Year Plans, and it is indeed a matter of relief and satisfaction that the Land Acquisition Act of 1894, by and large, stands up to the requirements of project authorities for acquisition of private land for them without undue delay.

The Land Acquisition Act, is rightly called an enactment of exceptional character. It aims at promoting important public interests and to the interests of such paramount importance, private interests may justifiably be subordinated.

Compulsory acquisition of property necessarily involves expropriation of private rights in the property acquired. But it is also a fact that private rights in land are *ipso-facto*, limited. A tenant may, in usual parlance, be called owner of land he holds, in terms of law he is the owner of only tenancy rights in the holding and State is the real owner of land in its jurisdiction. A tenant therefore cannot resist a compulsory acquisition of land for public purposes and he is paid compensation not in lieu of ownership, but only in lieu of tenancy rights over the land which are taken away from him.

Another significant feature of the land acquisition act, is that even though it seeks to acquire private land for public purposes compulsorily, it does so under a set procedure and not in an arbitrary manner. Section 5 A of the Act provides for hearing objections to the compulsory acquisition. A declaration under section 6, that the purpose of acquisition is public one, is necessary. Under section 9 (I) persons interested are given opportunities to appear personally or by agents before the Collector to state the nature of their respective claims in the land and the amount and particulars of claims to compensation.

Here it is relevant to note that land owned by the Government need not be acquired. The possession of such land is formally transferred under orders of the Government.

It must be remembered that the objective of acquisition of land for public purposes in a summary manner, is achieved on the basis of three fundamental propositions incorporated in the Act. (1) The Act empowers the Government to acquire land needed for public purposes. (2) it confers upon the private individual whose land is thus compulsorily acquired a corresponding right to receive compensation thereof and (3) it provides for a summary determination by the Collector of the area and value of the land and apportionment of compensation and also provides for a judicial determination thereof by a special Civil Court.

It is also worth while to bear in mind the peculiar status given to the Collector under the Act. He has a quasi-judicial status and functions as an agent of the Government. This ensures summary disposal of cases of acquisition without intervention by Civil Court though he is entitled under Section 45 of the Act to the service of his notices in the manner provided under the Civil Procedure and Code; he can also examine witnesses though he cannot administer oath to them and admit and weigh the evidence before him.

In this context it must be said, as a parenthesis, that it is essential to have a wide measure of co-operation between the Executive Engineer, and the Land Acquisition Officer. Mutually their relations are complimentary though due to certain external and avoidable factors and attitudes they appear to be exclusive and divergent. They should understand and appreciate each others view-points and resolve difficulties with a spirit of co-operation and help. Land Acquisition Officer should not fail to understand that in order that the project be completed within the time schedule, the Executive Engineer must be given possession of land as early as possible and the latter on his part must also bear in mind that he must hasten slowly in order to enable the Collector to follow the procedure laid down by the law.

LAND ACQUISITION

The execution of the Chambal Canal Works commenced in January 1955, though the work of preliminary surveys and construction of buildings were taken-up as early as 1951. The acquisition of land got its momentum in the later stages of the expansion of canal excavation after the establishment of all canal construction divisions. In the beginning land acquisition work was entrusted to the Sub-Divisional Officer, (Revenue), Sheopur until an independent Land Acquisition Unit for Chambal organisation was established in December 1956.

The Survey and Settlement Unit was a part of the Land Acquisition Office with its technical, revenue and survey staff. But this branch has now been separated from the Land Acquisition Unit with effect from 1958.

Range and Scope of Acquisition

(A) *Main Canals and Branches.* The extent of land acquisition for the Main Canal and its branches is detailed below:—

	Location	No. of Villages affected	Distance in Miles
1. Main Canal Upper.	From Barodia Bindi to Sheopur Pargana to Sabalgarh.	112	112
2. Ambah Branch.	From Sunhera Village in Sabalgarh Tehsil to Udatgarh in District Bhind.	80 (app.)	89
3. Lower Main Canal.	From Sunhera to Jora Alapur.	38	33
4. Morena Branch.	From Alapur to Manpur in Morena Tehsil.	37	35
5. Mau Branch.	From Tundila Village to Village Adotkhar in Mehgaon Tehsil District Bhind.	32	38
TOTAL		299	307

(B) *Distributaries*: Land will also have to be acquired for distributaries which will spread like a network throughout the area as covered by the Main Canal and its branches. A Separate Division with its Head-Quarters at Baroda in Tehsil Sheopur has been established and the work of distributaries has commenced in full swing up to the first 40 miles of Upper Main Canal.

Process and Nature of Execution of Work

(C) *Proposals in respect of land to be acquired*:— This is preliminary and very important process. Executive Engineers of each Division with the help of revenue staff (i.e. Survey & Settlement Officer's staff) obtain an accurate data of the land. Proposals for land to be acquired contain sketch (map) of field, Khasra containing (i) S. No. of the land (2) name of the cultivators (3) land revenue of the particular plot etc. These details are further scrutinised by the Survey & Settlement Unit in respect of the area, land revenue etc., and after this scrutiny these papers are sent to the Tehsildar of respective villages who again certifies the validity of the particulars and then the papers are sent to the Sub-Divisional Officer for his remarks in respect of transfer of land to the Chambal Organisation.

After these preliminaries the proposal is sent to the Land Acquisition Officer for transmission to Government for publication of notification under section 6(1) and (17) of the Land Acquisition Act.

(B) *Execution of notices under section 9(1) and (9) (3)*: After the publication of the notification in the Government Gazette notices under section 9 (I) and 9 (3) are issued and investigation in accordance with Land Acquisition Act follows.

(C) *Transfer of Land and Possession thereof*: Possession of land to be acquired is handed and taken over in the presence of the representatives of the Chambal Organisation as well as revenue authorities, and necessary entries in revenue papers are made. Besides this in cases where question of damage to standing crop, house, wells etc., arises, punchanamas of the estimated value of the anticipated damage owing to the excavation of canals, are prepared.

Progress of Land Acquisition

From the figures (given below) of land acquired in five Tehsils of Morena District it is seen that so far 12,996 Bighas of private land and 6,915 Bighas of Government land was handed over to the Chambal Project and payment of Rs. 10,76,061 and 43 nPs has been made in lieu of compensation to the cultivators. Out of the proposals submitted possession of 1905 Bighas of private land is yet to be handed over to the Chambal authorities.

(1) Schedules showing proposals sent and possession handed over to Chambal Department (Figures in Bighas)

	PROPOSALS			POSSESSION		
Name of Tehsil	Private Land.	Govt. Land.	Total	Private Land.	Govt. Land.	Total
1. Sheopur	7122	4076	11,198	5,608	2,978	8,676
2. Bijaipur	806	3077	3,883	804	2,386	3,190
3. Sabalgarh	3220	1189	4,409	3,220	1,177	4,397
4. Jora	3194	388	3,582	2,747	352	3,099
5. Morena	559	48	607	527	22	549
TOTAL	14901	8778	23,679	12,996	6,915	19,911

N.B. (Figures have been complied to nearest Bigha)

(2) Schedule of Compensation paid

S. No.	During Financial Year	Sanctioned allotment	Actual Disbursement
1.	1956-57	Rs. 1,00,000.00	Rs. 99,289·54
2.	1957-58	Rs. 3,00,000.00	Rs. 2,19,377.78
3.	1958-59	Rs. 4,00,000·00	Rs. 3,28,187.24
4.	1959-60	Rs. 4,12,500.00	Rs. 4,12,275.54
5.	1960-61	Rs. 3,04,000.00	Rs. 16,931.33
Total			Rs. 10,76,061.43

(3) Detailed Schedule of Compensation Paid (Canal Wise)

Serial No.	Name of Branch	Financial Year					Total
		56-57	57-58	58-59	59-60	60-61	
1.	Upper Main Canal ..	99,289.54	2,16,610.58	84,606.79	1,11,021.88	12,432.57	5,23,961.36
2.	Lower Main Canal ..	—	—	1,46,654.14	1,69,978.54	3,838.44	3,20,471.12
3.	Ambah Branch ..	—	2,767.20	96,926.31	1,31,275.12	660.32	2,31,628.95
	GRAND TOTAL ..	99,289.54	2,19,377.78	3,28,187.24	4,12,275.54	16,931.33	10,76,061.43

(4) Detailed Schedule Showing Compensation Paid Under Various Major Heads of the Canal Branches

Serial No.	Major Heads	Sub-Head			Total
		Colony	Canal	Borrowpits	
1.	Upper Main Canal ..	17,241.02	4,89,678.94	17,041.40	5,23,961.36
2.	Lower Main Canal ..	9,915.72	2,63,594.77	—	2,73,510.49
3.	Ambah Branch	—	2,74,410.82	4,178.76	2,78,589.58
	TOTAL	27,156.74	10,27,684.53	21,220.16	10,76,061.43

(5) Abstract of Expenditure

1. On Compensation of land etc.	10,76,061.43
2. On Establishment of Land Acquisition and Survey & Settlement.	2,54,000.00
	13,30,061.43

(N.B. All figures are ending June, 1960)

As seen from the above the amount spent on establishment is not the criterea compared to compensation paid. This is on account of innumerable holdings and narrow strip of land acquired for canals and distributaries etc. which involves huge amount of work compared to the compensation to be paid.

Acquistition Work in Arrears

This falls into two categories namely:—(1) Arrears of work after the publication of notification. (2) Remaining work for which proposals are yet to be received from Division of Executive Engineers. As regards (i) it has been verified that the work of acquisition of land for payment of compensation for the Main Canal and Lower Main Canal covering a distance of 145 miles has more or less been done, during a period of about three years upto the end of August 59. (ii) Proposals for the acquisition of land for the area covered by remaining branches having a distance of 148 miles are yet to be received from the Divisions, of Chambal Project.

To this should be added acquisition of land for distributaries and borrow-pits, commencing from the starting point of the Main Canal from the Village Barodia-Bindi in Sheopur Tehsil and stretching upto Gohad Tehsil in Bhind District. It is felt that at least a period of two years is necessary for the completion of this work.

NATURE OF WORK & TIME FACTOR

Land Acquisition cases have to be dealt with proper care and after fulfilment of all the statutory obligations of the land acquisition act including the time required for publication of the notification and the declaration under the act as well as per the notices to be served on parties and adjournment to adduce evidence. There are several other external factors, as stated below, which also cause delay:

(a) Proposals sent by Divisions are required to be scrutinized in the land acquisition office and at times they are returned to Divisions for corrections, as found therein. Spot inspection of damage to the crop has got to be done and damage is assessed on the basis of the ruling rates of cereals from the Mundies.

(b) After an award is given the cultivator is informed to be present in the office to receive the amount of

compensation which is paid on the indentification made by Patel and Patwari who also have got to be present. In case of absence of either, the payment is held up.

(c) Heirs and successors of the deceased cultivators have got to produce authenticated certificates to claim the amount of compensation on behalf of the deceased. This is not easily done and in time available and the payment is therefore delayed.

(d) In order to expedite disbursement of compensation and to eliminate avoidable inconvenience to the cultivators payments are generally made at the respective Tehsil Head-quarters. And thus all possible efforts are made to facilitate the cultivators to receive their compensation with the least inconvenience.

(e) Co-operation of revenue officials is essential at the time of spot inspection for preparation of Panchanamas and verification of titles of the cultivators from revenue records, Khasaras and maps of Revenue Department.

In short, it can be said, that Land Acquisition work is proceeding satisfactorily and the tempo of the progress so far made should enable the Land Acquisition Officer along with his staff to acquit themselves creditably and well as is expected of any office functioning under the project.

NOTICE

TESTING OF FLAMEPROOF ELECTRICAL EQUIPMENT

The Council of Scientific and Industrial Research wish to draw the attention of manufacturers and others interested to the provision of facilities for testing flameproof enclosures of electrical apparatus at the Central Mining Research Station, Dhanbad, Bihar. Manufacturers are invited to take advantage of this facility for having their products tested for purposes of approval. Enquiries may be addressed to the Director.

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Health in a Project

By Dr. R. P. BHORASKAR

PROJECTS in our country are increasing and with that the health of the workers in a project is also receiving more and more attention. So much so we are apt to call it a special branch of medicine, where casualties are common and epidemics threaten and where every worker, unless assured and guarded against ill-health, tends to rush back home.

Every project requires a lot of labour of different categories. Naturally, on account of increased opportunities in employment, labour from different parts of the country congregate there. Of these labour, a few may be infected and their congregation along with others offers a very easy opportunity for spread of diseases or outbreaks of epidemics.

The project township has only one purpose: to house the people employed in the project. It is therefore, temporary and administered by an administrator. This is quite unlike a city where different groups of people with different avocations live. The city have a permanent population. Even under adverse circumstances, the people in a city, therefore, tend to stay on in their homes while under such circumstances the population in a project township try to leave it. This adversely affects the target and the project execution gets delayed.

The close proximity of stored water or abundance of forest in the valley may give rise to epidemics or even endemics of malaria, unless properly guarded against and treated extensively in a planned manner. Malaria tends to produce chronic ill-health and debility amongst workers, who cannot then put up their best. Consequently there is a tremendous loss of man power, and work hours of individual workers get diminished. For a worker, health is the only wealth. He can put in hard work only when healthy. An unhealthy worker tends to slacken causing material and monitary loss to the project.

Malaria still is one of the greatest menace to our country and more so to a project. In Chambal Hydel Scheme, we, therefore, had to take regular steps to fight this menace. Medical Dept. of the Government helped us with a liberal supply of D.D.T. We sprayed two or three rounds of D.D.T. and larvicidal spray of Malariol every year in the colonies. Paludrine was distributed to combat the latent malaria and every labourer was given Paludrine once a week compulsorily. This was very effective and malaria was sufficiently controlled bringing down the splenic index from 18 in 1953 to 2 in 1959. 32 deaths of cerebral malaria was recorded in 1953 while in 1959 cerebral malaria was practically unknown.

Drinking water supply in a project is of great importance. Unprotected water supply and insanitary surroundings spread water-borne diseases like dysentry, typhoid and cholera. The township as well as the work site, therefore, have got to be provided with filtered and chlorinated water abundantly. Use of dirty polluted river water has to be forbidden. Otherwise no one knows when a carrier may pollute the water supply and infect the whole township.

We supplied filtered and chlorinated water in abundance. The total consumption of filtered water in colonies was 4½ lakh gallons for a populace of 20,000. This gives 22 to 25 gallons of filtered water per capita per day. Water-borne diseases in this project were unknown. There was not a single case of typhoid nor a single epidemic of cholera.

Proper sanitary arrangements under the guidance of health department is of utmost importance. Drainage, disposal of refuse and night-soil, trenching grounds and septic tanks, and preservation of foodstuff—all contribute to maintain health of the population of the project. Both the colonies of Chambal Hydel Works had proper drainage though the colonies were only temporary. More than half the latrines were flush ones, though some of them were Ujjain type pit latrines. The sullage water was disposed of sufficiently below the downstream of the dam. In labour colonies pan latrines were provided and disposal of the night soil was done by gangs of sweepers using night soil carts into trenching grounds.

Prolonged hospitalisation and rehabilitation of injured was often found necessary as the workmen cannot be properly attended to in their houses. This called for a large number of beds both in the wards and rehabilitation centres for the injured. While under treatment, his dependants have also to be provided for. Though compensated by the Workmen's Compensation Act, the personal loss caused cannot always be translated into standard financial adjustment. Prolonged idleness, delayed compensation due to time-taking formalities and a state of compensation mindedness—all go to convert a healthy worker to a shelter-seeking personality and a disgruntled member of the society.

At the Gandhi Sagar Dam site the hospital was started as a small unit; but as necessity demanded it gradually expanded to a 64-bed one. Equipped with X-Ray, pathological laboratory and a modern air-conditioned operation theatre the hospital provides

both surgical and medical treatment. Maternity-wing of this hospital offered free natal service to employees of the project. Its anti-natal clinic as well as the post-natal visits were also popularised by the Lady Health Visitor. Family planning also was taken in hand and successful attempts were made to bring home to labourers the importance of planning their families and its importance to the nation. Free medical services were offered to all injured during employment. Facilities such as transport and medical attendance were made available free and free diet was also provided. The medical and health organisation of this project did all that was possible to allay the sufferings of the injured and diseased and employees of the project naturally looked to it with faith and hope.

STATISTICAL DATA OF HOSPITAL'S ACTIVITIES

	1956-57	1957-58	1958-59	1959-60
Daily average of out-door patients	415.07	517.63	625.29	653.39
Daily average of in-door patients	22.04	39.26	42.86	54.96
Operations				
(a) Major	144	244	280	298
(b) Minor	697	902	891	835
(c) X-Ray	620	1634	2113	2388
Laboratory investigat-ions	59	578	1632-	2172
Maternity cases in Hospital	44	173	190	195

One interesting item of the medico-social work carried out by the organisation was that of creches and Child Welfare Centres at the work site. Many female workers engaged in the construction used to bring their children to the work site and the children had to be cared for. In 1956 one unit of creches accommodating about 50 children was started which, in no time, became very popular. The demand increased and three more units at various places of works were started. They were controlled by the Lady Health Visitor with one receptionist and 2 to 3 supervisors in each unit. Children were given free milk, food and clothing. There were tutors teaching mainly cleanliness and good manners. The Government of Madhya Pradesh helped generously with supplies. Weaklings were specially taken care of by supplying supplementary diet and multivitamins. To promote health as well as the sense of health a Baby Show competition was arranged every year on the 14th of November (Bal-diwas) and healthy babies were rewarded.

The team of medical workers of this project have done what best they could do. And they, in their turn, got what best the people of the project could give: their faith and gratitude. Here are the words of a very distinguished visitor:

"I have been coming to the Gandhi Sagar fairly often and have seen this Hospital grow, so to say, from the rock bottom. It has done wonderfully well. I saw it yesterday after 25 months, full of patients looking extremely happy and contended. My congratulations to all concerned who work with such devotion". Kailasnath Katju, (*Chief Minister, Madhya Pradesh*), 21st April, 1960.

(Continued from page 118)

INDUSTRIAL RELATIONS AT GANDHI SAGAR DAM AND POWER STATION

reading room, and indoor and outdoor games of carrom, chess, choupat, ring tennis and volley ball.

Bhajans and kirtans are frequently arranged in the Hall by groups of different communities on occasions of religious and other festival days.

Three occasions every year, viz., the Republic Day, Independence Day and Ganeshotsab are celebrated on grand scale, when all classes of employees join together in the jubilations in the form of different games and sports, cultural programmes and parties and picnics. During Ganeshotsab celebrations which last for 9 days, variety entertainment programmes of music, dance, drama, magic show, folk songs, comics and orchestra are arranged locally and outside parties are also invited.

Every year on the occasion of the Childrens Day, the 14th November, Baby Show Competition is held and 10 prizes are awarded to healthy babies, five for each colony. About 150 to 200 babies partake in the Show.

On the occasion of Republic Day, the 26th January, 1960, Clean House Competition was held in three labour camps consisting of 350 houses. 21 prizes, 7 for each camp, were awarded to the winners of the competition.

Since Gandhi Sagar Colony and the Construction Camp are located at a distance of 3 miles, facilities of free transport exist for the officers and staff of the project to enable them to attend their duties.

CONCLUSION

To sum up, efforts have not been spared by the project with all its limitations to create homely atmosphere for all classes of employees so that they may put their best in the cause of nation.

Organisation Set-up of Chambal Project

IN the year 1948 at a meeting held under the Chairmanship of the then Minister for Works, Mines and Power of the Government of India, it was decided to construct three dams and a barrage across Chambal river—one dam in Madhya Bharat (now Madhya Pradesh) and two dams and a barrage in Rajasthan. The Madhya Bharat Government engaged a consulting engineer for advising the Government on the construction of the dam and the actual execution was started under the regular Chief Engineer, P.W.D. of the State who was assisted by a Superintending Engineer and 2 Executive Engineers for the project work.

To regulate and co-ordinate the detailed investigation connected with the Chambal Valley Development Scheme, the Central Government set up a Technical Board under the Chairmanship of Director, C.W. & P. C. with the two Chief Engineers of Madhya Bharat and Rajasthan as its members. The Chambal Technical Board continued till 1953 when detailed investigation of the projects was completed.

In the year 1950 the Government established a separate office of the Chief Engineer for the Chambal Project with his headquarters at the work site. The organisation functioned till 1954 with a skeleton staff attending mostly to surveys, preparation of the project and estimates. The first stage of the project was sanctioned in November 1954 and active construction works was started from that year. The organisation was therefore suitably expanded to meet the rising tempo of construction. In the year 1955, a Circle office was established for canal work in addition to the Circle office in charge of head works. In the year 1956 the Electrical Circle was established for power station and transmission lines. During the peak construction period, 1959-60, the Chief Engineer of the project was assisted by 3 Superintending Engineers one each for head-works, canal works and electrical works. The Chief Engineer was also provided with an additional Superintending Engineer to work as chief technical examiner for the project. The details of organisation of each Circle are furnished below.

(*i*) *Head works*:—The Superintending Engineer incharge of head works, viz., Gandhi Sagar Dam and the power house has under him five Executive Engineers and a Stores Officer of the rank of an Executive Engineer. Out of the five Executive Engineers two were responsible for construction of the dam and power house, one for construction of buildings, roads and collection of materials such as sand, stone, rubble, etc.; one for rehabilitation works and the other for construction plant, workshop, works power station and water-supply, etc. A principal medical officer in-charge of medical and health department and an Industrial Relations Officer to look after welfare of labourers were also provided for the Superintending Engineer, head works. A Central Stores under a Stores Officer with adequate staff was established at head works to procure and supply necessary materials and equipment to both the dam and electrical circle.

(*ii*) *Canal Works*:—The canal works are spread over a vast area. The Superintending Engineer, canal works is provided with 8 Executive Engineers, out of them one is attached to Circle office to work as P.A. to Superintending Engineer, one is responsible for construction of canals by machinery, one for construction of distributaries and the rest four for construction of canals, C. D. works, buildings, etc. Each Executive Engineer has a length of about 40 miles of canal under him.

Similar to head works, the Superintending Engineer (canals) has been provided with a Medical Officer and a Labour Welfare Officer. The canal organisation is likely to be expanded further by two more Executive Engineers with a view to achieve targets within the scheduled time. One more division under an Executive Engineer is sanctioned for execution of water courses to ensure early utilisation of irrigation water by the cultivators and a second division for construction of distributaries.

(*iii*) *Electrical works*:—The Superintending Engineer (electrical) has been provided with 10 Executive Engineers, one is attached to Circle office to work as P.A. to Superintending Engineer, one is responsible for construction of buildings at various places, one for erection of penstocks, sluice Gates, trash-racks, etc., one for erection of turbines, generators, etc., one for preparation of specifications, designs, etc., and the rest five for erection of grid sub-stations and transmission lines.

(*iv*) *Chief Technical Examiner*:—The Superintending Engineer in charge of technical examination and quality control is assisted by 2 Executive Engineers, one each for quality control and administrative audit of head works and canal works.

There is a Chief Accounts Officer for the project who is principal drawing and disbursing officer. The Chief Accounts Officer is assisted by 3 Assistant Accounts Officers, one each for canals, head works and electrical works. The Assistant Accounts Officer makes payment of all claims after precheck and renders accounts to the Accountant-General.

The work of land acquisition, payment of compensation to persons of their rehabilitation area is done under the Revenue Commissioner of Division

(Continued on page 113)

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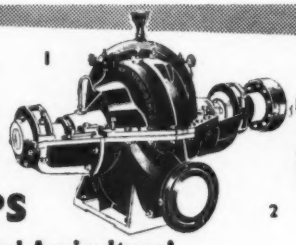
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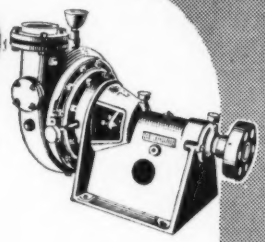
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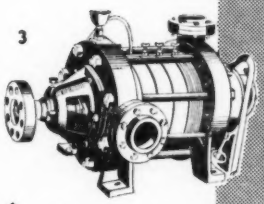
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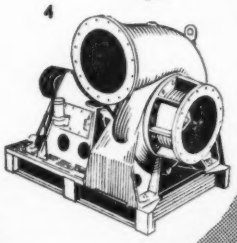
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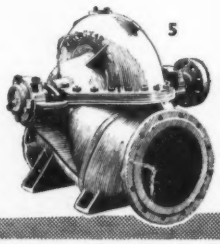
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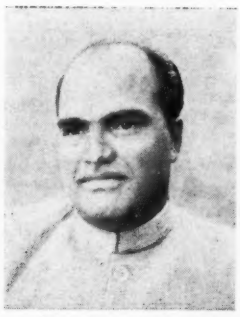

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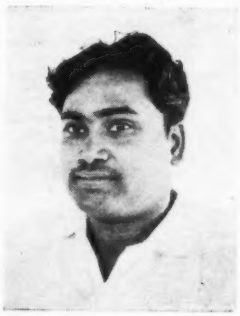

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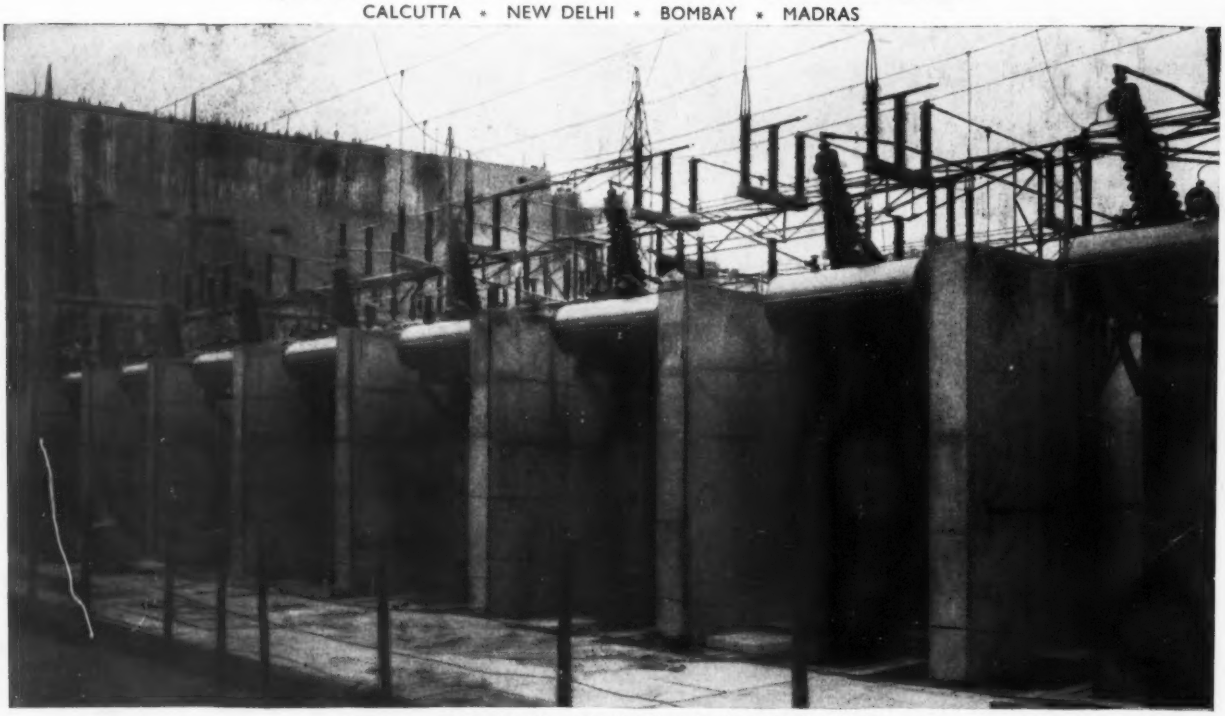

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